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Next Month

A series of tests on joint leakage were recently conducted on a California pipe line. These will be discussed in detail in the April issue by a prominent engineer on the Pacific Coast.

With large refinery construction programs in prospect during the coming summer another of a series of timely articles on estimating construction costs will appear.

Of interest to those in the development and production branches of the industry will be a discussion of the latest developments on bottom-hole choking in wells; a new and important development in drilling machinery and operating data on the results, and the second of the valuable series of articles by Hyman Ledeen, the first of which appears in this issue.

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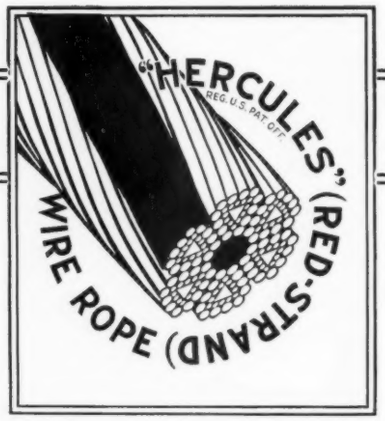

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The Course of Oil

By K. C. SCLATER

A Barrier to Progress

ONE of the pernicious results of the repeated attacks on proration in the East Texas field is the increasing uncertainty and fear for the future that each succeeding attack breeds among producers. It makes no difference whether the uncertainty and fear are real or imaginary, the effect produced is the same. So often have proration enforcement orders had to be changed because of court injunctions that producers are in a perpetual quandary as to what course the future is likely to take. Instead of going ahead and making plans for the future, they are inclined to adopt a waiting attitude. There is little encouragement for them to proceed with normal plans whereby they can anticipate the future and decide accordingly on suitable equipment for wells and for field requirements.

Evidence adduced at the Federal Court hearing held at Houston, Texas, several weeks ago is now being considered by the judges. At this writing, producers await with no little concern for the court to hand down a decision. Meanwhile, an air of uncertainty prevails that is a barrier to progress in a return to more stabilized conditions in the East Texas field. So widely have the possibilities of this field been heralded that the demoralizing effect produced by this uncertainty goes far beyond the bounds of the Texas and Mid-Continent fields.

Scientific Reservoir Control

COMPARED with the average oil field in the United States the oil fields of Persia, as exploited by the Anglo-Persian Oil Company, are veritable laboratories for the scientific production of oil on a vast commercial scale. As the fields are in the hands of one company, there is a freedom of action in applying scientific methods of reservoir control that is absent in an oil field of diverse ownership interests such as is common in the United States. What has been accomplished there is an ample demonstration of the value of a closely co-ordinated development program whereby practical work and research are carried on concurrently. The field practice obtaining there may be taken as an indication of the future trend toward a more intensive application of scientific methods in the production of oil. Amazing results have been obtained.

Edgewater encroachment is so effectively controlled that, in the Masjid-i-Sulaiman field in particular, produced continuously since 1911, no wells have yet been abandoned on account of water, despite the fact that this edgewater is sensitive to variations in reservoir pressure arising from an unequal withdrawal of oil. When oil wells in the top of the structure go to gas or have an excessive gas-oil ratio, they are shut in. It is a surprising fact to learn that the date when wells have gone to gas has corresponded closely with estimates made four years ago. Vital research work is continuously being conducted. The results are immediately put to practical use. Drilling campaigns and production estimates are planned ahead with an uncanny degree of accuracy. The application of science in the production of oil apparently is making greater strides than many are inclined to believe.

Long-Range Outlook for Petroleum

STATISTICS on petroleum presented at the New York annual meeting of the A.I.M.E. are of especial significance at this time as indicating in some degree the prominent place that the oil industry must continue to occupy. The world's proven oil reserves are estimated at more than twenty-four billion barrels. Of this amount 61 per cent, or twelve billion barrels, is in the United States, and 33 per cent, or eight billion barrels, in the Near East fields of Russia, Iraq and Persia. Up to the end of 1932 the past production of petroleum totaled twenty-three billion barrels. In other words, the total amount of oil produced to the end of 1932 about equals the present total proven oil reserves. This ratio does not hold for the United States, for although the estimated proven oil reserves of this country are twelve billion barrels, or 48 per cent of the world's total, it is to be noted that 65 per cent of past production, or about fifteen billion barrels, has been produced in the United States.

Another momentous point in this connection was brought out in a paper dealing with the relation of coal and petroleum in the United States. In 1900 the total energy derived in the United States was obtained from three principal sources, namely: 91.3 per cent from coal; 4.3 per cent from petroleum and its products; 4.4 per cent from hydro-electric power. In 1930 the percentages were 60.3 from coal, 31.6 from petroleum and its products, and 8.1 from hydro-electric power. A forecast for 1950 gives 46.6 per cent from coal, 45.3 per cent from petroleum and its products, and 8.1 per cent from hydro-electric power. It is shown that the demand for energy has been increasing at a greater rate than the growth of population; also that, as indicated by the figures just quoted, the market for petroleum products in this country will about double in the next 20 years. No other major industry can show such a favorable long-range outlook. It is well to ponder these figures to get a glimpse into the future of the oil industry.

HIGHLIGHTS in OILDOM

Panhandle Crude Price Reduced

Early in March, Humble Oil and Refining Company posted lower prices for Texas Panhandle crude production. The reductions ranged from 6 cents to 11 cents per barrel. Gray County crude, which was lowered 6 cents, has a spread from 30 to 40 cents.

The Humble also posted a price of 30 cents flat for Fisher and Jones Counties, Texas. This is the first time that company has listed crude from these counties. The reductions made are in line with prices being paid by some competitors.

New Pool Opened in Oklahoma

A most important field development from the standpoint of new production occurred early in March, with the opening of a new producing field five miles north of the Greater Seminole area by the Carter Oil Company. The well, located just south of Keokuk Falls, in the extreme northern end of Seminole County, flowed a total of 1575 bbl. in 17 hours, or at the rate of almost 93 bbl. an hour for the entire period. The producing horizon is the Misener sand, topped at 4090 feet.

Conroe Production Is Doubled

The allowable daily production of the Conroe field in Montgomery County, Texas, was recently increased from 18,500 to 35,000 bbl. by the Railroad Commission. Part of the allowable will be allocated on a basis of 20 bbl. per well and the remainder in accordance with acreage holdings.

A new order for development of this important pool requires that wells be spaced 933 ft. apart and 466 ft. from any property line. Also the gas-oil ratio was limited to 2000 cu. ft. per bbl. of oil and numerous safety regulations were included in the order, which became effective March 1.

East Texas Activity Declining Rapidly

Activity in the East Texas oil field is declining rapidly and within a few weeks will likely take second place to the booming Conroe field of the Texas Gulf Coast. From a peak of around 900 active drilling operations, East Texas operations have now dropped to only 189 wells as shown on the latest drilling report. Locations, which at one time totaled approximately 200 per week, are now made at the rate of between 20 to 30 weekly.

Slash in California Prices

The Standard Oil Company of California reduced prices paid for crude oil effective March 5 from 6 to 32 cents per barrel. The new price range is from 49 to 96 cents a barrel. The sharpest cut was made in the Elwood Terrace field, where 37-deg. gravity A.P.I. oil was cut to 96 cents from $1.28.

Oklahoma Allowable Increased

Oklahoma's allowable oil production for March will be 466,484 bbl. daily, according to the Corporation Commission's order. This is the largest total allowable output in nearly a year. The principal increase was in the Oklahoma City field, which will be permitted to produce 152,814 bbl. per day.

Allowable in East Texas Given Huge Increase

Effective March 19 to June 1, the Railroad Commission will permit a production of 400,000 bbl. daily in the East Texas field, an increase of 110,000 barrels. This action resulted from a close study of existing conditions in the field that showed, despite the commission's previous allowable outlet of 290,000 barrels, approximately 400,000 bbl. were being moved from the field daily.

The new proration order changes the previous method of distribution. About 400 marginal wells in the field have been allotted an allowable of 16,000 bbl. daily, leaving 384,000 bbl. to be distributed on a "proratable allowable," which will be split three ways. One-third will be on a well basis, one-third on bottom-hole pressure and the remaining one-third on sand thickness.

A check of oil movements by main pipe lines, tank cars and gathering lines of local refineries from the East Texas field has revealed that distribution of crude oil has exceeded production by nearly 100,000 bbl. daily since January 1. Tank car shipments have been increasing rapidly, some days reaching 100 cars and there has been a concentration of empty cars in the vicinity—obviously in anticipation that proration might be broken.

Much of the surplus oil shipped from the field has been overproduced oil, as shown by a comparison of storage figures for the past few months. There has been a slight decline in storage, several major companies having drawn on stocks. Magnolia Petroleum Company recently bought 115,000 bbl. of storage oil; Sinclair-Prairie Oil Company 40,000 bbl.; Empire 38,000 bbl.; and Shell Petroleum Corporation 38,000 barrels. All this oil was purchased at the posted price of 50 cents per barrel.

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Latest Activities in the Oil Fields

SEVERAL developments in the Conroe field, Montgomery County, Texas, were of considerable importance during the past month, particularly the completion of a number of wells that will play a part in extending or defining the field. A southwest extension producer, although good for a flow of 125 bbl. hourly through a ½-in. choke, indicated the nearness of edgewater when it early produced as much as 38 per cent salt water. The depth before plugging back, 5121 ft., was apparently 5 ft. below the water level and may be taken as an indication that the pool will not extend much farther toward the southwest.

Two miles west of Conroe, a test of George W. Strake's failed to find production and, while not close enough to alter the estimated productive area, it nevertheless shows that the field may soon be defined. Successful completion of a number of minor extensions was made throughout the month, but these perhaps ranked second in importance to the indications that the field may be defined at a comparatively early date.

In Southwest Texas, Humble Oil and Refining Company completed a wildcat well in Bastrop County that apparently is one of the best Serpentine sand wells in the state. The well flowed 65 bbl. the first hour through a ½-in. choke at 2577 feet. Much interest is being displayed in the pool and already many locations have been announced.

Further possibilities for the deep pay horizon in the Saxet field of Nueces County seem to be attracting considerable attention among Southwest Texas oil operators. Until recently the field had created little interest, but now some very worthwhile producers have been completed. These, while producing from the same horizon, are in widely separated sections of the field and if a uniform sand condition prevails in the intervening areas early development of a major pool should result.

In California, the completion of a 4500-bbl. well in the Kettleman Hills North Dome field has slightly extended the producing limits and further proves the importance of the northwest end of the structure. The well is about ⅜ of a mile northwest of the previously accepted field limit.

Oil men of Oklahoma are still uncertain about the producing possibilities of the new Wentz pool in Noble County. The Shell Petroleum Corporation et al's recent completion, now on the swab, is producing only 135 bbl. of oil. The Stanolind-Amerada well has also shown a steady decline, bringing its production under 500 bbl. per 24 hours. The discovery well drilled by Wentz and associates had a similar production history before it was shut in. However, it is possible that all these wells may be edge producers and, because of this possibility, much importance is attached to tests now drilling, the latter being off the northwest-by-southeast line on which the three producers are located.

AVERAGE CRUDE OIL PRICES

California		Oklahoma	.44
Playa Del Rey	$ .69	Arkansas	.25
Coalinga	.49	Louisiana	
Long Beach	.75	North Louisiana	.44
Montana	.75	Gulf Coast	.54
Wyoming	.44	Illinois	.62
Colorado	.40	Kentucky	.57
New Mexico	.30	Indiana	.40
Texas		Ohio	
North Central	.44	Lima	.70
Panhandle	.33	Wooster	.70
West Texas	.30	Michigan	.85
Gulf Coast	.54	Pennsylvania	
Darst Creek	.35	Bradford	1.47
East Texas	.50	Corning	.70
Kansas	.44	West Virginia	1.12

Production and Refining Figures Furnished by the American Petroleum Institute

Crude Runs to Stills, Gasoline and Gas and Fuel Oil Stocks
Week Ending February 25, 1933

(Figures in Barrels of 42 Gallons Each)

DISTRICT	Per Cent Potential Capacity Reporting	Daily Avg. Crude Runs to Stills	Per Cent Operated of Total Capacity Reporting	Total Motor Fuel Stocks Thousands of Bbls.	Gas and Fuel Oil Stocks Thousands of Bbls.
East Coast	99.1	453,000	70.9	14,689	6,879
Appalachian	95.0	78,000	57.8	1,979	917
Ind., Ill., Ky.	97.5	316,000	74.5	8,137	3,264
Okla., Kans., Mo.	84.9	203,000	52.1	5,043	2,851
Inland Texas	56.4	93,000	52.3	1,620	2,130
Texas Gulf	97.7	407,000	75.1	6,269	6,331
Louisiana Gulf	97.3	106,000	74.6	1,607	2,166
No Louisiana-Ark.	88.5	50,000	63.3	323	648
Rocky Mountain	90.8	30,000	21.7	1,460	580
California	94.6	384,000	44.3	15,103	98,999
Total	91.6	2,120,000	60.0	56,230	124,765
Total	91.6	2,072,000	58.7	55,461	125,310

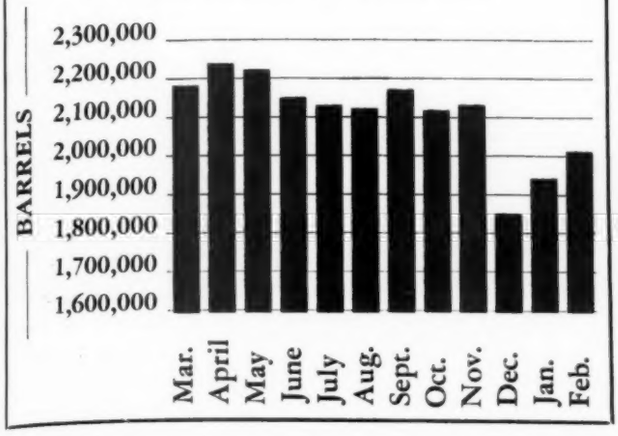
Daily Average Production
(Figures in Barrels)

	Week Ended Feb. 25 1933	Week Ended Jan. 28 1933	Week Ended Feb. 27 1932
Oklahoma	521,500	370,100	431,900
Kansas	108,550	94,100	100,250
Panhandle Texas	47,800	46,200	47,600
North Texas	46,550	46,250	47,300
West Central Texas	25,650	24,400	23,650
West Texas	157,750	157,800	178,750
East Central Texas	59,450	48,500	54,600
East Texas	*302,400	*294,100	304,750
Southwest Texas	50,350	51,650	51,200
North Louisiana	29,000	29,900	28,200
Arkansas	31,950	32,150	33,850
Coastal Texas	128,450	134,500	109,700
Coastal Louisiana	33,150	34,400	26,150
Eastern (not including Mich.)	91,000	89,900	101,700
Michigan	13,850	15,300	13,700
Wyoming	31,550	31,300	36,900
Montana	5,600	5,500	7,700
Colorado	2,650	2,700	3,600
New Mexico	37,100	36,550	37,350
California	468,300	463,400	499,200
TOTAL	2,192,600	2,008,700	2,138,050
Texas	818,400	803,400	825,200

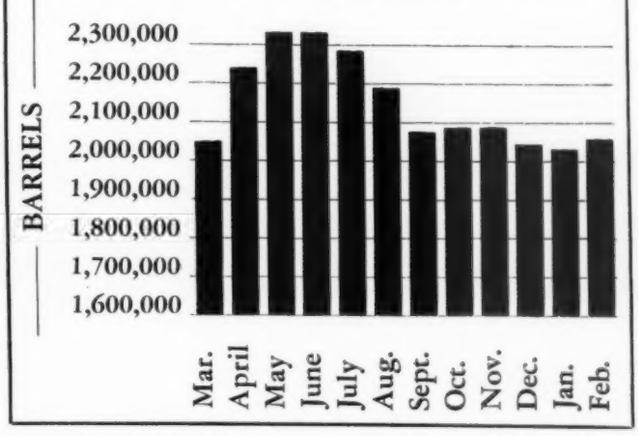
* These figures reflect only that oil produced in accordance with proration allowables and does not include oil produced under protection of injunctions or otherwise.

NOTE: Stocks at refineries, except in California district, which includes stocks on finished gasoline and engine distillate at refineries, water terminals and sales distributing stations and amounts in transit thereto.

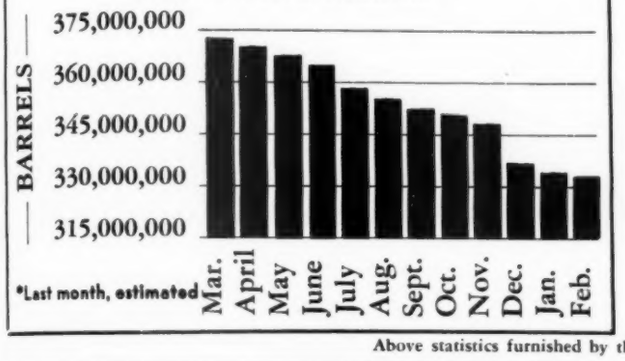
U. S. Daily Average Production for the Past Twelve Months



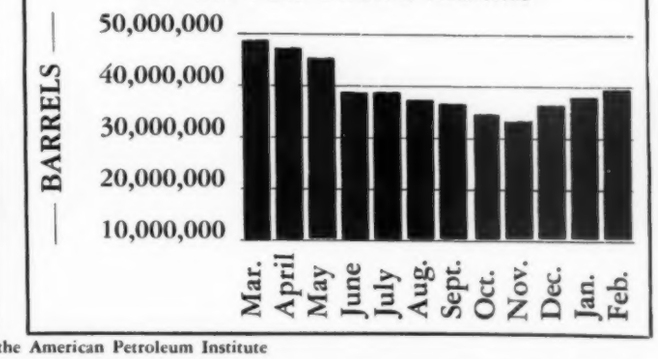
Daily Average Crude Run to Stills for the Past Twelve Months



U. S. Crude Oil Stocks for the Past Twelve Months*



Gasoline Stocks in U. S. Refineries for the Past Twelve Months



Above statistics furnished by the American Petroleum Institute

Summarized Operations in Active Fields for February, 1933

Fields	Completions	Producers	Locations	Rigs	Drilling Wells	Depth of Production	No. Casing Strings	Gravity of Oil	Type of Tool Used
Texas									
East Texas	190	178	236	68	132	3600	2	40	Rotary
Duval County	31	27	17	8	38	2300	2	22	Rotary
Conroe	65	64	89	32	92	5200	2	38	Rotary
Oklahoma									
Oklahoma City	7	5	8	4	13	6500	3	39	Rotary
Kansas									
McPherson	20	13	5	7	37	2900-3400	2	38	Rot.-Cab.
Ellsworth Arch	10	5	3	7	25	3300	4	37	Cable
California									
Kettleman Hills	0	0	3	3	14	8300	3 or 4	40	Rotary
Long Beach	7	7	3	2	24	7000	3	26	Rotary

Field Activities by States for February, 1933

State	Completions		Producers		Locations		Rigs		Drilling Wells		Production, 1932 (In Barrels)
	February	January	February	January	February	January	February	January	February	January	
Arkansas	4	4	0	0	4	25	20	13	31	37	11,907,000
California	24	20	22	17	19	16	17	7	88	82	178,128,000
Colorado	1	2	1	1	2	1	8	6	60	56	1,177,000
Illinois	1	2	1	1	....	....	1	1	11	12	4,661,800
Indiana	20	18	7	7	....	....	4	2	65	64	804,000
Kansas	40	40	22	26	24	39	41	46	96	107	34,300,000
Kentucky	21	20	11	18	....	....	6	15	45	56	6,264,000
Louisiana	22	29	11	12	42	26	33	37	123	119	21,478,000
Michigan	14	16	9	13	19	17	45	35	68	66	6,729,000
Mississippi	7	1	3	1	....	....	4	1	16	10	Gas. Prod.
Montana	....	2	....	2	....	3	6	7	36	40	2,449,000
New Mexico	8	6	6	5	8	13	6	4	54	49	12,511,000
New York	3	3	3	2	....	....	2	2	8	8	3,501,000
Ohio	45	56	33	49	....	....	38	37	110	108	4,597,000
Oklahoma	88	87	52	52	59	84	121	115	327	304	152,621,000
Pennsylvania	32	38	29	33	....	....	7	6	90	93	12,403,000
Texas	560	473	386	362	576	454	279	297	720	882	311,069,000
West Virginia	21	27	20	21	....	....	9	10	35	34	4,472,000
Wyoming	3	1	0	1	....	....	8	9	64	69	13,359,000
Total	914	845	614	623	753	678	655	651	2047	2196	781,845,000

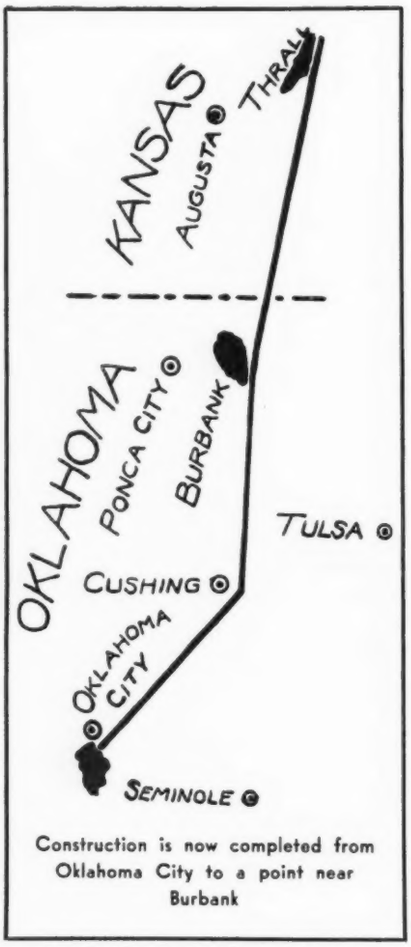
Progress of Major Pipe Line Work

By WARREN L. BAKER

PHILLIPS PETROLEUM COMPANY'S program for expansion of its Oklahoma-Kansas crude oil distribution system has been enlarged to include the looping of the old 6-in. line from Thrall, Kan., to their Kansas City refinery, a distance of approximately 80 miles. With this project the program now involves the laying of a total of 290 miles of line to provide greater transportation facilities on the north end of the Phillips system, which will now be thoroughly adequate to pick up crude deliveries at Thrall emanating from the company's new 8-in. line under construction from the Oklahoma City oil field. Building of the Thrall-Kansas City loop is in charge of Phillips engineers.

Kelly-Dempsey Company, contractors on the 210-mile extension from Oklahoma City to Thrall, are making rapid progress, and, in consideration of the especially convenient location of the company's storage facilities, it should be possible to start shipments of Oklahoma City crude at once.

By March 1, some 65 miles, or more than one-fourth of the extension, had been completed, bringing the line to the Phillips tank farm, located at Cushing, Okla. The next objective is the Burbank, Okla., tank farm.



ROUTING OF THE PHILLIPS LINE

The Tide Water Pipe Line Company's 8-in. welded line from the Conroe field to Humble, Texas, a distance of approximately 20 miles, has been completed by the Apex Construction Company. This is Conroe's third pipe line outlet, the other two lines being operated by the Humble Pipe Line Company and The Texas Pipe Line Company. The present capacity of the Tide Water line is approximately 25,000 bbl. daily. Tide Water's purchases in the field now amount to about 10,000 bbl. daily.

Two additional crude oil lines to serve the rapidly expanding Conroe field are being planned. The Sun Oil Company is reported to have completed two surveys from Conroe to Humble, Texas, where it proposes to connect a lateral with the company's main trunk line to the Port Neches basin. Construction of that line will not start, however, until a number of pending production deals in the Conroe field are consummated.

If decision on proration by a three-judge Federal Court is favorable, the Channel Transport and Marketing Company (Golding & Murchison) will probably construct an 8⅝-in. outlet from the field to the American Refining Company's tank farm on the Houston ship channel, a distance of approximately 40 miles.

Aerial surveys have been made by the H. F. Wilcox Oil & Gas Company for an 80-mile, 8-in. oil line from the Oklahoma City field to the Wilcox refinery at Bristow, Okla. Action on the project is being held up until a decision is handed down by the Oklahoma State Legislature on proration regulations now under consideration.

Natural Gas Lines

Surveys have been completed and the right-of-way taken by the Moran Corporation of Texas for the laying of a natural-gas trunk line from the Conroe field to Houston. This 10-in. gas carrier will require 35 miles of pipe. The Houston destination of the line is the Sinclair Refining Company's plant; and the ship channel will be crossed via the tunnel built by Sinclair a year ago. The line will supply industrial plants with fuel.

Lycoming Natural Gas Corporation, Wellsboro, Pa., has made preparations to lay a 40-mile, 20-in. natural gas line connecting the new Hebron field in northern Pennsylvania with the company's 100-mile trunk line to Syracuse, New York.

Michigan Natural Gas Corporation, Muskegon, Mich., now plans the construction of a 40-mile line from the Mt. Pleasant, Mich., field to towns in Gratiot County. It will be recalled that Michigan Natural was recently granted a permit to build a 60-mile line to Bay City and Saginaw.

Natural Gas Pipe Line Company of America, Chicago, is proceeding with plans for expanding its Iowa service. Approximately 200 miles of construction work is involved, including an 88-mile, 8-in. line from Oskaloosa to Waterloo, Iowa, and a 52-mile, 4-in. line from the Texas-Chicago trunk line at Fruitland, Iowa, to Ft. Madison in the same state.

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The Month's Activities in Refining*

By F. R. STALEY

THERE were several developments during the past month in foreign refining centers. The Henry Vogt Machine Company recently shipped from New York harbor one of the longest and heaviest pieces of equipment ever handled in that seaport. It was a 60-ton bubble tower, 7½ ft. by 113 ft., consigned to the La Plata refinery in Argentina.

Liquefied petroleum gas will soon be manufactured and marketed in Argentina for domestic and industrial uses by the Yacimientos Petroliferos Fiscales. The product will be extracted from natural and cracked gas.

According to reports, a 2000-bbl. refinery is planned for St. John, New Brunswick. Construction work, it is expected, will start at an early date.

There continues to be a number of improvements and enlargements announced for eastern United States plants. One is the Cities Service Company plan to make alterations and install a distillation unit at its East Braintree, Mass., refinery. Alco Products, Inc., will build a 1500-bbl. distillation unit for the Oil Creek Refining Company at Titusville, Pa. The Standard Oil Company of Ohio is building a 1200-bbl. asphalt emulsion plant at Cleveland, Ohio, and expects to have construction work completed within two months. The Quaker State Oil Refining Company plans a number of improvements at its Farmers Valley, Pa., refinery.

The Ethyl Gasoline Corporation has completed a new laboratory adjoining its engineering research building in Detroit, Mich. Here its departmental work will be conducted in the future. Previously, chemical research work has been carried on at the Yonkers, N. Y., plant.

A refinery for the new West Holdenville, Okla., pool is being erected by the Crescent Refining Company. It will be a cracking and skimming plant.

Two new refineries are proposed for the East Texas area. Both plants will be located in West Gregg County to serve the north end of the field. One will be owned and operated by W. C. Goforth and the other by H. D. Landers.

Employees at the Marathon refinery, Bristow, Okla., have been placed on full working time in preparation for the construction of a new Kellogg unit.

The Chicago Bridge and Iron Works has been awarded a contract for the erection of several storage tanks at the Coastal Petroleum Corporation's plant, Mobile, Ala.

The Magnolia Petroleum Company is building a gasoline stabilizing unit at its Corsicana, Texas, refinery.

The Caldwell Refining Company will build a small refinery at Caldwell, Idaho, while the Grey Oil & Refining Company plans a small refinery at Greybull, Wyo.

Figures in red show per cent refining capacity operated.

*All statistics as of March 1.

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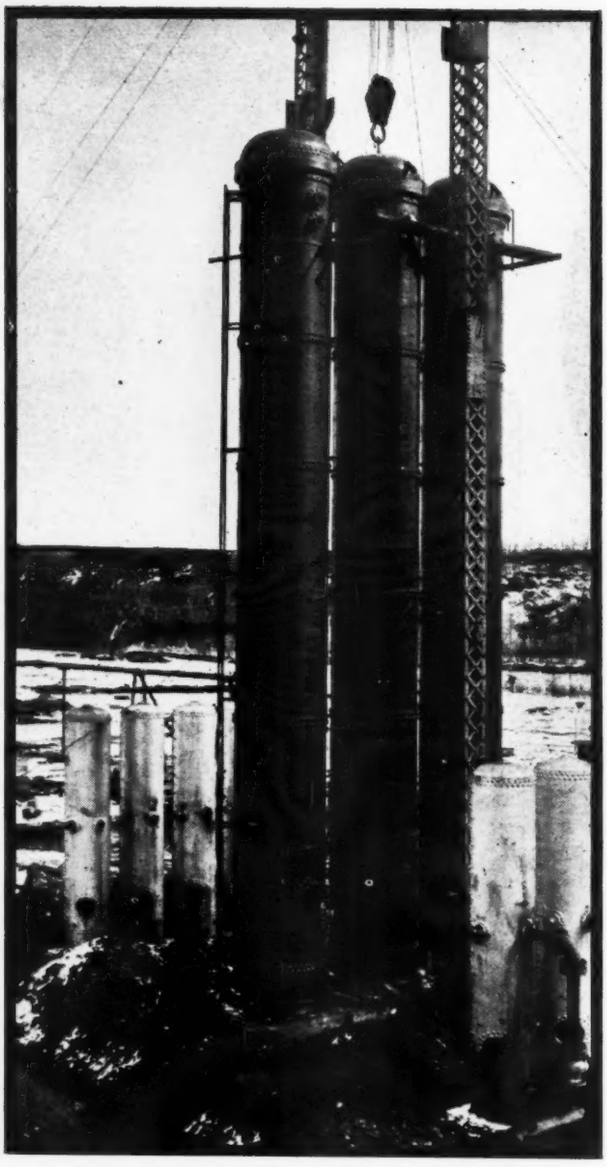


Absorbing columns, separators used for wet and dry gas scrubbers

THE first commercial natural gasoline plant in Canada is being erected in the Turner Valley field of Alberta by the Royalite Oil Company, subsidiary of Imperial Oil Company of Canada. Declining separator and drip naphtha recoveries produced with the natural gas, coupled with the Alberta Government's firm stand on conservation in enforcing its regulations for physical waste, have made a natural gasoline plant essential for Turney Valley. Another added incentive for a plant is the contract between the Royalite Oil Company and the gas company serving Calgary and other towns in Southern Alberta whereby the gas company is obligated to take all its requirements from the Royalite Oil Company for the life of the field. This market has been supplied since 1924 with sweetened but unprocessed gas. Average requirements last year were 25,000,000 cu. ft. a day with a peak load of 60,000,000 cu. ft. Heretofore, conditions in the valley were too uncertain with regard to the government's attitude on conservation to justify the investment in a plant.

The Turner Valley Conservation Board, an Alberta Government Commission, made gas and naphtha production tests during the summer and fall of 1932, making available many valuable data on Turner Valley. The total estimated reserves as of November 24, 1932, were approximately 512,000,000,000 cu. ft. and the gas after passing through the separators and drips had a weighted average gasoline content per 1000 cu. ft. of 0.18 U. S. gallons (tests made by standard charcoal method). The average analysis of the waste gas of many Turney Valley wells made by the Dominion Government (Podbielniak apparatus) is shown in Table I.

The tests were made to assist operators in promulgating a voluntary unit operating agreement. Failing this the information was to be used to allot and prorate equitable natural gas quotas to each well. At the present time, the first part of March, 1933, the Alberta Legislature has before it the government engineers' plan, showing estimate of reserves and proportional allotment of gas quotas, together with independent plans as submitted by several groups of operators covering the same sort of estimates. There has been a determined fight by some operators to steer clear of any unit operation. This fight is based on the fact that the field is too far developed, and that there is too great a range between the producing pressures of the newer and older wells to make any sort of unit operation equitable. The last government order issued, December 3, 1932, allotted 200,000,000 cu. ft. per day to 85 wells. This quota of gas to individual wells forces the companies to operate their wells in the older developed areas at a working pressure somewhere between 600 lb. and 800 lb., and the wells in the newer areas at working pressures between 1000 and 1400 pounds.

Average closed-in top-hole pressure of the field of date November 24, 1932, using pressure contour map, was 1288 lb., the highest recorded pressure 1790 lb., and the lowest 680 pounds. Most of the operators hold the pressure between 200 lb. and 400 lb. on their separators (all are single-stage separator operations) so that the pressure available for the gasoline plant operation will be between 200 and 400 lb. at the wells. All gas coming from the separators through the gathering lines to the plant will be metered through Foxboro orifice meters after leaving the separators.

All operations in bringing the gas from the wells through the plant will be synchronized. The plant will operate on a 300-lb. working pressure and the separator pressure at the

TABLE I

(Results are percentages by volume)

Well or Source	Date Test	Methane %	Ethane %	Propane %	Butane %	Pentane %	Total Hydrocarbons %	Carbon Dioxide %	Oxygen %	Nitrogen %	Helium %	Specific Gravity (Air = 1)
Highest % Methane Content of Well	Aug. 31 1926	96.1	1.4	0.9	1.0	0.59	97.40	0.00	0.44	2.15	0.009	0.677
Lowest % Methane Content of Well	Oct. 31 1916	85.1	7.4	4.1	2.3	1.11	96.57	1.05	0.26	2.12	0.005	0.715
Purified Gas Calgary City Mains	Aug.-Sept. 1929	89.1	5.5	3.2	1.3	0.90	———	———	———	———	———	———
Crude Naptha from Separator	Sept. 30 1917	4.1	4.4	9.4	16.6	65.50	———	———	———	———	———	———

Gasoline content of the gas may be low and the gas analysis shows too small an amount of heavier fractions due to the method of taking the samples for both tests.

Pressure Gasoline Plant

By F. W. SHELTON
Production Engineer
Calgary, Alberta, Canada

wells will be only enough more than 300 lb. to deliver the gas to the plant. The separator pressures will not be varied. The control of this factor will be governed at the intake to the plant and the plant held responsible for maintaining this equilibrium. The same gathering lines as used for the scrubbing plant will be used for the plant. These lines consist of 16 miles of 6-in., 3 miles of 8-in., and 8 miles of 10-in. pipe, all heavy seamless steel.

The plant site is in the Turner Valley field and is part of the general Royalite plant site that includes the scrubbing plant, electric generating station and crude naphtha pumping station. The plant is of the high-pressure, unit type, with a capacity of 75,000,000 cu. ft. per day, using three 55-ft. Foster Wheeler absorbers with bubble caps and trays. Bubble caps and trays were assembled on the job. The absorbing medium is mineral seal oil manufactured at the Imperial refinery, Calgary. A 10 per cent cut of this oil will be continuously reboiled and conditioned at the plant.

The still is an Alco combined still and rectifier operating at 75-lb. working pressure, with a new type of reheater between still and heat exchangers. A 60-ft. Braun fractionating tower working at 175-lb. pressure will make all commercial cuts for which a market is now obtainable. A new type of reboiler and heat exchanger is used between the still and the fractionating tower.

The pumping equipment consists of two 6-in. by 8-in. triplex horizontal, motor-driven pumps with grooved belt drive, one to handle lean oil and the other as a standby for lean oil and fat oil. The still and refractionating tower are fed by Gould Hivol direct-connected Simplex steam pumps for high viscosity fluids; one is 7-in by 18-in. and the other 5-in. by 12-in. The electric plant has been augmented by an additional 156-Kva. Canadian Westinghouse generator direct-connected to Cooper-Bessemer vertical engines. This makes four units in all. All water used is creek water, softened and cooled through tubular coolers, circulated with direct-connected motor-driven Canadian Westinghouse centrifugal pumps. All plant phases are under automatic control. All high-pressure and low-pressure valves are stainless steel trim. Three-way Merco Nordstrom valves are used on the heat exchangers. All pipe work is flange and weld, using tube bends. All lines will be overhead and none buried. Separators are used as scrubbers before and after the gas passed through the absorbers. The steam plant consists of five 125-hp. Oilwell boilers.

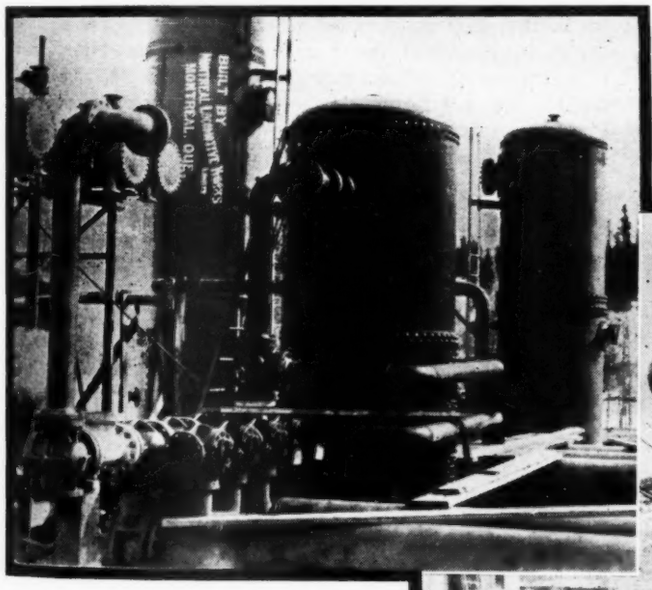
The dry or processed gas will go from the gasoline plant to the scrubbing plant, which will use what gas is necessary for the gas company requirements, and the remainder will be burned until such time as additional markets are found.

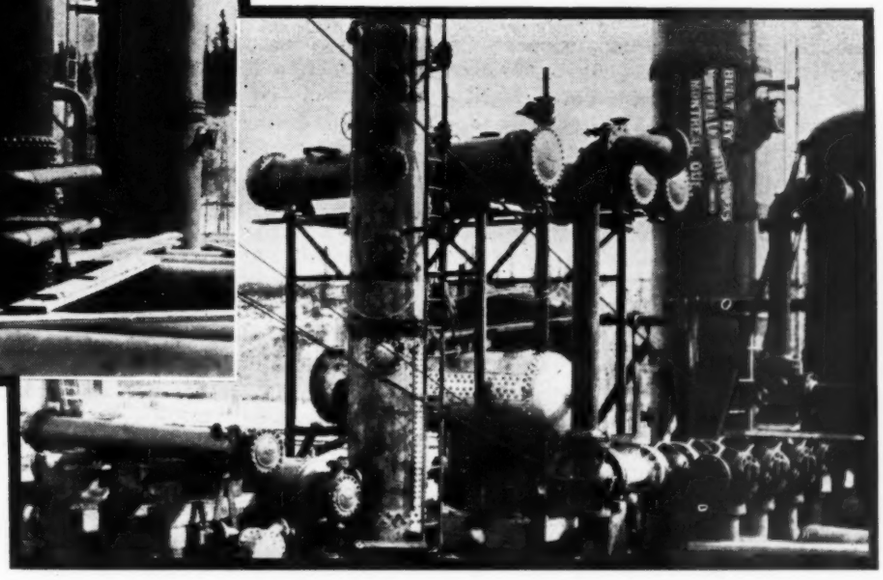
At the present time the gasoline plant will process only a blending natural gasoline, with a vapor pressure of about 10 lb.; this product will be stored in 580-bbl. horizontal 10-lb. vapor pressure steel tanks and subsequently batched into the Imperial Refinery at Calgary through the present 4-in. crude naphtha line. The plant will not sweeten the gasoline as this will be done after it reaches the refinery. The wet gas carries from 1 to 1½ per cent sulphur.

The construction work is being done by the Royalite Oil Company itself. Sam Coultis is the general field superintendent. The supervision and plant construction is directly under Charles Ward, who was formerly connected with the Carter gasoline plant in Salt Creek, Wyoming.

The Royalite and Imperial Oil Companies have been operating for some time under the 5-day week and 8-hour day plan at the old daily wage scale. Under this labor adjustment more than 15 per cent more men are at work than ordinarily would be employed, at a total monthly wage only slightly less than they received before. This same plan is in force on the gasoline plant's construction work, which is employing 80 men, all of whom were former employees of Royalite. The operating personnel when the plant is finished will be made up from some of the men used on construction and will be under the 5-day plan.

It is the opinion of many interested people in Alberta that this plant is the forerunner of additional development There are still many gas development opportunities in the Prairie Provinces, with so far only very limited natural gas distributive facilities and markets.





Above: Heat exchangers, flash tower and three-way valves

Right: Heat exchangers, valves, still and base of fractionating tower with reboiler ready to hook up

Drilling and Producing Con

Strict attention to condition of drilling mud and uniform casing programs necessary because of high-pressure gas in shallow sands. Field is produced with low average gas-oil ratio.

Small crater alongside the county highway formed by the blow-out of Standard Oil of Kansas Madeley No. 2 well, which is several hundred feet away

ALTHOUGH it is little more than a year since the discovery well was drilled, Conroe field today is one of the major oil pools in the Gulf Coast region. It is one of the few pools at the present time in the United States that is being actively developed, and has the distinction of being one of the first pools of diversified ownership in the Gulf Coast the development of which since discovery has been closely regulated by the Railroad Commission of Texas. As it was discovered while the East Texas field was at the height of its development, vigorous steps were immediately taken by the Railroad Commission for the regulation of drilling and production—especially when it appeared likely to develop into a field of major proportions.

Conroe field is in east central Montgomery County, six miles southeast of the town of Conroe, which is 41 miles north of Houston on U. S. highway 75 and is the town from which the field gets its name.

Wildcat drilling had been in progress in the Conroe area since 1929, but it was not until December 13, 1931, that the discovery well was brought in. This well, the Geo. W. Strake No. 1, South Texas Development Company in the Theo Slade Survey, was completed at a depth of 4991 ft. in the upper Cockfield formation for an initial daily production through a ½-in. choke of 100 bbl. of oil of 54-deg. gravity A.P.I. and 15,000,000 cu. ft. of gas, with a reported pressure of 1435 lb. at the casinghead. As brought in, this well virtually produced nothing but wet gas. Some months later it was deepened to the lower Cockfield (known as the Conroe sand) and brought in as a good oil producer with a low gas-oil ratio. It was not until June 5, 1932, however, that the first well, the G. W. Strake, South Texas Development Company No. 2, was completed in the Conroe sand, the main producing horizon in the field.

At this writing about 250 wells have been completed as producers and it is estimated that the proven productive area in the field is now more than 15,000 acres in extent. Effective March 1, 1933, the allowable production from the field was increased from 18,500 bbl. to 35,000 bbl. per day. Of the 27 or more operators active in the field the four companies now holding the largest proven acreage are the Humble Oil and Refining Company, the Tide Water Oil Company, the Sun Oil Company, and The Texas Company.

The main productive oil horizon, the Conroe sand, is about 200 ft. below the top of the Cockfield formation in the Claiborne series. This, the lower Cockfield, has an average thickness of 56 ft. and an average porosity of 26 per cent. On the north side of the structure the upper Cockfield, or that above the Conroe sand, produces only gas, but on the south is quite prolific of oil and gas. The depth to the top of the Conroe sand varies from 4855 to 5219 ft. throughout the field. Surface elevations in the field range from 130 ft. to 220 ft., with 165 ft. as the probable average elevation above sea level.

With the exception of controlling the high-pressure gas, which is a formidable problem in some parts of the field, the difficulties of drilling the formations in the Conroe field are not especially great. The rotary is used exclusively for drilling and completing wells. Various types of bits, fish-tail and other drag-type, are in general use; rock bits are also employed where hard streaks are encountered. Both 6-in. and 4-in. drill pipe are in use, but the latter size predominates.

Substantial casing programs in this field have been adhered to. In that part of the field where blow-outs have occurred the Railroad Commission regulations require that three strings of casing be set and securely cemented. Owing to the serious trouble that has resulted from cratering the required depth of the intermediate string in this area has been increased recently (Feb. 27, 1933) from 900 to 1400 ft. by the Railroad Commission.

Down to 300 ft. surface sands are encountered; from there to 1200 ft., the formations are principally water sands and shales. For surface pipe it is customary to set about 350 ft. of casing, the exact amount depending upon where a suitable landing point is found, which is cemented with from 125 to 200 sacks cement. It was customary in some of the earlier wells drilled to set the intermediate string at 1400 ft., but this practice is adhered to now only in the area in proximity to where the blow-outs have occurred. From five to seven surface sands are encountered, adequate protection from which is obtained by setting 900 ft. of water string. The oil string is set just above the Conroe sand and consists of about 5000 ft. of 7-in. O.D. 26-lb. seamless steel, grade "C" A.P.I. casing for the average well in the field.

There are three casing programs in general use by the major operators in the field: (1) Up to 350 ft. of 15½-in. 70-lb. casing for the surface string; from 900 to 1400 ft. of 10¾-in. 40.50-lb. casing for the water string; and about 5000 ft. of 7-in. O.D. 26-lb. casing for the oil string. (2) Up to 350 ft. of 13⅜-in. 54.50-lb. casing for the surface string; from 900 to 1400 ft. of 9⅝-in. 36-lb. casing for the water string; and about 5000 ft. of 7-in. O.D. 26-lb. casing for the

Conditions in the Conroe, Texas, Field

By

K. C. SCLATER

Flooded crater of Madeley No. 2 well. In the center of the picture can be seen escaping gas bubbling and burning at the surface of the water

oil string. (3) About 900 ft. of 10¾-in. O.D. 40.50-lb. casing for surface and water string; and about 5000 ft. of 7-in. O.D. 26-lb. casing for the oil string.

Strict regulations in regard to casing are enforced by the Railroad Commission in the Conroe field. It is required that casing be tested by pump pressure. In making this test the mud-laden fluid in the casing must be replaced by clear water and a pump pressure of at least 1000 lb. per sq. in. applied. If the drop in pressure at the end of 30 minutes exceeds 100 lb. the casing will not pass the test and corrective measures must be applied. It was the practice before the recent regulations were issued to test the surface casing to 1000-lb. pressure and the 7-in. oil string to 1500-lb. pressure.

It is general practice in the field to cement all casing by the pump and plug method, using from 150 to 200 sacks of cement for the large surface casing, a minimum of 200 sacks of cement for the water string, and 200 or more sacks of quick-setting cement for the 7-in. oil string. To insure a good cement job around the steel set shoe a float collar is run on the 7-in. casing one joint off bottom. This practice is sometimes followed also in cementing the water string.

Comparatively loose unconsolidated formations at the surface with underlying sands, below which in turn are strata carrying large volumes of gas under high pressure have, in some parts of the field, been the indirect cause of serious blow-outs and consequent cratering over a large area. This condition has been the most serious one to contend with in the Conroe field. The secret of combatting it is in constantly maintaining close control of the mud, and in equipping the well with a blow-out preventer on both the surface pipe and the oil string. It is the practice in the field to use one blow-out preventer of the hydraulically-operated type (this, in fact, is required and written into the regulations of the Railroad Commission) and the other of the regular type. While drilling, the blow-out preventer is tested by the drilling crew at least once every tour and on most drilling wells the well crew holds a drill every other tour to test out the efficiency of the emergency blow-out prevention measures in use.

Up to the present writing seven wells in the field have been out of control. Of these, two wells, Standard Oil of Kansas Madeley No. 1 and Madeley No. 2, were the most disastrous blow-outs in the field. The shallow sands underlying several hundred acres in the vicinity of these wells have become highly charged with gas and at four wells in this area, the Humble Oil and Refining Company's Madeley No. 11 and Madeley No. 28, and Harrison and Abercrombie's Alexander No. 1 and Alexander No. 2, gas started blowing out around the outside of the surface casing. To relieve this condition in the cratered area relief wells are being drilled to a depth of 300 or 400 ft.; small portable rotaries with 2-in. drill stem are being used for this work. These wells are being cased and cemented with 7-in. O.D. casing.

Great vigilance is exercised in checking the mud weight, especially when nearing critical depths in the well. Following the dictates of good practice based on experience in the field, some operators check and record the mud weight every hour, for which purpose special hydrometers are used; other operators maintain a check by weighing the mud in a container of known capacity.

It has been ascertained by field study that the surface formations in the Conroe field are very poor in mud-making qualities, so it is customary in starting a well to use commercial clay, or to obtain mud from the sump of an adjacent completed well. A satisfactory 10½-lb. drilling mud of low viscosity and good colloidal properties is obtained after a depth of about 900 ft. is reached; and from there down to 3600 ft. Below this depth the mud weight decreases; but the viscosity and the colloidal properties increase, a condition that necessitates the exercise of extreme care. It is good practice in the field to carry 9.7-lb. to 10.5-lb. mud of low viscosity to facilitate the quick release of entrained gas when running in or coming out of the hole. To reduce the viscosity the mud is chemically treated or is thinned with water.

When a gas sand is encountered in the upper Cockfield at about 4750 ft. in certain parts of the Ransome House Survey and Wilson Strickland Survey, the weight of mud is increased from 10.0 lb. to 11.5 lb. per gal., and the viscosity kept as low as possible by thinning with water or chemical treatment; it is carried at this weight the remaining depth. Farther to the north, west, and east, mud weighing 9.8 lb. to 10.0 lb. per gal. suffices for the entire depth. In the southern part of the field mud weighing 9.6 lb. per gal. is carried to about 4800 ft., at which depth gas sands in the upper Cockfield are encountered. From this point on 10-lb. mud is carried to the bottom of the hole.

Owing to the serious blow-outs that have occurred in the vicinity of the Standard Oil Company of Kansas Madeley leases, the weight of the mud used in this area is extremely high. Mud weighing from 14 to 15 lb. per gal. is carried continuously from the time the well is spudded in; and frequent treatment of the mud is necessary in order to maintain a

viscosity low enough that the release of entrained gas will be adequately facilitated.

Investigations on mud fluid in completing wells in the field have shown that by proper conditioning of the mud beforehand, the running and landing of the 7-in. casing is facilitated and a reduction in pump pressure of as much as 200 lb. obtained.

All wells are surveyed at 500-ft. intervals from about 1500 ft. downward. The Railroad Commission regulations require that the maximum deviation shall not exceed five deg. from the vertical when the well spacing is 20 acres or more, four deg. where spacing is ten acres and less than 20 acres, and three deg. where the spacing is less than 10 acres per well. Drilling contracts all have a clause limiting the maximum amount of deviation to four degrees. No difficulty has been experienced in keeping holes straight and there is little loss of time in fulfilling this requirement. Surveying holes for deviation from the vertical has become a routine test that is carried out with little or no interruption to actual drilling operations.

Coring practice in the field is not uniform and various types of core bits are in use. Some operators start coring after the Cockfield formation is penetrated a certain amount, depending on the structural position of the well, and cored continuously until the well is completed. In wells down dip coring is started 200 ft. from the top of the Cockfield formation and in those higher on the structure the starting point for coring may be 300 ft. or 350 ft. from the top of the Cockfield. Other operators core just enough to ascertain the top of the pay sand. Many operators in the field believe in coring to find a suitable landing point, and to determine the top of the productive sand and the thickness and nature of the free gas zone above the oil. Proper well completion in this field would seem to demand this.

All wells are completed with wire-wrapped screen. These are of Layne & Bowler, Stancliff and Emsco make. From 40 to 60 ft. of screen pipe is used in the average well opposite the oil sand. Screens of various slot sizes, from 0.008-gauge to 0.018-gauge, are in use in the field, the most widely used size of slot by far being 0.010-gauge.

Since the upper part of the productive sand may carry either free gas or oil with a high gas-oil ratio, care is taken in completing the well to guard against the possibility of producing the free gas, or producing oil with an excessive gas-oil ratio. If the pay sand is continuous, with no shale breaks, the casing is set through the upper part of the sand. In cases where a gas sand separates two oil horizons, the gas sand has been successfully shut off by means of two bootleg packers, one on each end of a joint of blank pipe set opposite the gas sand; care is taken, however, to set the packers on shale. Sometimes blank pipe is set through the gas sand and no packer set above the screen if the upper part of the pay sand is firm and of medium texture.

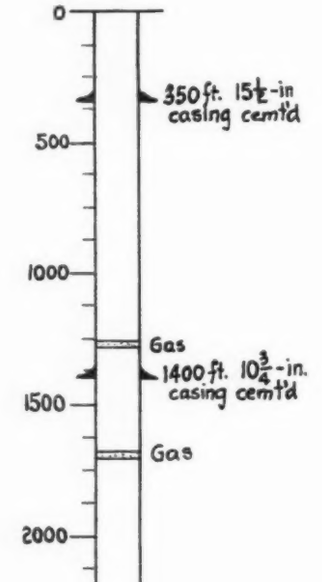
Wells are tubed to the top of the sand, usually with 2½-in. upset tubing. Wells are washed in with clear water, the operation taking from one to two hours. Swabbing is resorted to if the well will not flow. It takes on the average from 25 to 30 days to complete a well.

A Christmas tree is mounted on top of the tubing with valves and flow beans for controlling the flow. Most wells are produced through gas separators of 125-lb. working pressure into vapor-tight tanks.

On the earlier wells drilled subsequent remedial work has been done to reduce gas-oil ratios with considerable success. In wells where the screen was set too high, resulting in high gas-oil ratios, it has been pulled, the well deepened and new screen set. For example, on the original discovery well, which was virtually brought in as a wet gas well, producing about 100 bbl. of oil of 54 deg. A.P.I. gravity daily and 15,000,000 cu. ft. of gas on a ½-in. choke, deepening and resetting the liner resulted in a well of 72 bbl. an hour with a gas-oil ratio of 416 cu. ft. per bbl. Equally successful results obtained in other wells in the field is mute evidence of the advantages of using the sub-surface information obtained from coring and from accurate production records as a basis for the proper completion of subsequent wells drilled.

All wells in the field are produced by natural flow. The original reservoir pressure is estimated to have been 2275 lb. at 4800 ft. subsea level. The reservoir pressure as of March 1, 1933, was 2180 lb., indicating a total pressure drop of 95 lb. since the field was brought in. While high gas-oil ratios were common in the earlier wells drilled, the average gas-oil ratio for the field today is probably not much greater than 500 cu. ft. per bbl.; and there are many wells with a gas-oil ratio of 350 to 400 cu. ft. per bbl. To date about four million bbl. of oil with a probable average gas-oil ratio of 700 cu. ft. per bbl. has been withdrawn from the Cockfield formation in the pool. It would be a mistake to use the present figures to obtain a relationship between production and reservoir pressure drop as they are likely to be too inaccurate on account of the wells that have flowed out of control. More accurate estimates should be available at a later date.

The main producing horizon, besides having a large free gas cap, has also a water drive. The plane of the oil-water contact in the Conroe sand is about 4990 ft. subsea level. As the pay sand is relatively permeable, close control of the water drive and conservation of gas in the field will have to be maintained for efficient oil recovery.



Log of a representative well near the center of the Conroe field, showing the casing landings, the approximate position of the gas sands encountered and the Conroe sand, the main productive oil sand in the pool

Valve Efficiencies Are Maintained by Observing Diesel Principles

By SAM MONROE
Division Machinist Stanolind Pipe Line Co., Wirt, Oklahoma

IN the operation of Diesel engines, the importance of maintaining the exhaust and the intake valves at their highest efficiency has been proved beyond any question of doubt on the stations in Southern Oklahoma of the Stanolind Pipe Line Company. Absolute control of pressure and temperature in the cylinders was the basic principle of Doctor Diesel's theory in the development of the Diesel engine. All valve cages warp and distort under bolt pressures and forces of expansion and contraction. If precautions are not taken to minimize this condition one of the outstanding advantages of Diesel engine operation and efficiency may be lost. Recognizing this fact, the Stanolind Company, about three years ago, put into effect a system of repairing and servicing its engines, paying particular attention to the main valves, so that cylinder pressures and temperatures would be better and more fully understood by and under the complete control of the station operating engineer.

After grinding valves, cylinder tests are made by this company to determine efficiency of repair work in order to take full advantage of the basic principles of Diesel engine operation

It is an operating practice of the company to grind all valves under bolt pressure, having metal to metal joints between the valve cage and seat in the head, and to use just as little compound as is possible to accomplish a good grinding job. It is necessary to perform this work with the head removed from the engine. After the valves are repaired in this manner, the cylinder head is bolted into place but the valve-actuating levers are left off. The next operation is to spot the position on the outer or lower center and to connect a pressure gauge to an indicator connection on the cylinder in order to test the compression of the engine. This is done by filling the cylinder with air at 225-lb. pressure. When this pressure is reached the air supply is turned off and an accurate check is made of the length of time required for the pressure to drop from 225 lb. to 25 lb. If this pressure drop takes place in less than 10 minutes, the engine will not operate in keeping with the basic principles of Diesel efficiency. Any length of time above 10 minutes will give the desired results. It is found that in engines properly repaired, when tested in this manner, the average time for the cylinder pressure to drop from 225 lb. to 25 lb. is from 20 to 60 minutes.

Far-reaching advantages are gained from having valves that will pass this test. It lays the foundation for adjusting other working parts of the engine in such manner that combustion temperatures in the cylinder will be completely under the control of the operating engineer at all times. Full Diesel compression of 31 1/3 atmospheres can be maintained, for if the proper care is exercised in the injection of fuel, at the correct time and under conditions that combustion will maintain the maximum cylinder pressure over 10 per cent of the beginning of the power stroke, then the Diesel engine will be operating on exactly the same principle of expansion as the steam engine; and through skillful adjustments by the operating engineer cylinder pressures can be maintained from no load to full load, without variation of cylinder pressures and within the limits of cylinder temperatures that will not impair the efficiency or long life of the working parts.

As proof of these statements, it is interesting to note the difference in upkeep costs that this company has obtained through following out these principles. Repairs on exhaust and on intake valves have to be made only about once every two or three years, whereas, before this method was used about 30 days was the average life of these valves. The average life of the spray valve is now about six months. Formerly their average was about three days. In addition, blow-by at the piston rings has been completely eliminated. Contamination of the lubricating oil by carbon deposit has been almost entirely eliminated.

Pistons that have been operating continually for three years show no indication of distress. Under former grinding methods it was necessary to pull the pistons four times a year. Through the elimination of explosion shocks the life of the bearings and other working parts has been increased in equal proportion.

Any man who has once experienced the satisfactory results that are possible on full Diesel compression engines through the correction of defective combustion and pressure conditions in the cylinder, and who realizes the value of perfect control of cylinder pressure and temperature throughout the full range of load and speed variations, will not depart from these operating principles, instead he will always strive to follow them.

The Effect of Sa on the Efficiency of Explo siv

A UNIT quantity of liquid or solidified nitroglycerin produces more than seven hundred times its own volume of permanent gases at normal temperature, but because of the extremely high temperature at the moment of explosion, these gases are greatly expanded and occupy a much larger space. It is quite apparent that a fluid column, with only its gravity and frictional resistance, cannot completely hold these pressures and that the fluid must move up the hole at high velocity and with consequent absorption of power.

In considering this movement of fluid and heated disruptive gases up the hole, it must be borne in mind that their velocity is very high and that the disruptive effect is of sufficient intensity seriously to ravel or break down any tender walls of the hole above the pay, with a resulting expensive cleaning-out job and possible damage to the casing or casing seat.

When the choice of type of explosive or method of application is considered, it is admittedly true that while today we have only a rather vague mental picture of the actual effects from a shot in an oil well, it must be remembered that many of the pay strata outcrop somewhere, and that at or near such outcrops the stone may be mined or quarried, and that at such points the characteristics of the stone, except where it has weathered, are the same as at the point where it carries oil. In view of these facts, it is reasonable to assume that the disruptive effects of explosives on these strata—where the results are visual and can be studied—are, to a considerable extent, indicative of the effects that may reasonably be expected to result from explosives where the effects are not visual but where the ability of the explosive to do work is known.

The use of fluid stemming as a means of confining explosive energy in oil wells has until quite recently been almost universal and was deemed quite satisfactory. Experiments by the U. S. Bureau of Mines[1], explosives manufacturers, quarry operators and others, however, indicate that solid stemming of one kind or another, properly applied, is more effective.

Old ideas on the efficiency of fluid stemming ("stemming" as herein referred to applies to any material used to confine explosive energy and commonly referred to as "tamping") were probably based on the thought that, because of the high rate of detonation of oil well explosives, it was necessary only to create a condition of air-tight confinement to cause complete detonation, and that such detonation must do its work before there could be considerable loss of pressure by the upward movement of the fluid column. This theory is, of course, in a measure correct and is borne out by the results, but results with solid stemming indicate it to be far superior to fluid stemming.

As indicated by Bureau of Mines data obtained by laboratory tests and proved in mining and quarrying practice, the efficiency of any explosive is largely dependent upon the degree of confinement and the type and quantity of the stemming material used. It is generally agreed by explosives technicians that while "you can use too little stemming, you cannot—within reasonable limits—use too much." It has been found in well-shooting that the quantity of solid stemming should be determined by: (a) distance from top of shot to bottom of pipe or shoulder; (b) size of hole and quantity of explosives; and (c) quantity and kind of fluid in hole. The Bureau's data referred to indicate clearly that damp sand is the most efficient stemming material tested; hence, it has almost universal adoption in quarry blasting practice. While the use of damp sand as stemming in well-shooting is not new, it has not heretofore had general adoption because of the extra labor cost and seemingly greater shooting expense involved by its use.

Some operators who have been impressed with the sound, commonsense arguments in favor of sand-tamped shots have experimented with the method in sections of Texas, Oklahoma and Wyoming. On sand-tamped shots in deep wells, a duplex or double time bomb should always be used, and in shallow wells, either some time bomb or an electric squib.

A study of available data indicates that with sand stemming properly applied, as illustrated, it is possible—sometimes at a considerable saving in labor and pipe—to shoot within a few feet of the pipe without serious danger of injuring it or its seat, provided, of course, that all fluid is first carefully removed to a level below the casing seat and the bottom of the bridge.

It sometimes happens that the strata above the pay horizon are tender and have caving tendencies. In such cases, if fluid stemming is used, the disruptive wave of the explosion, in forcing the fluid column up the hole and in seeking the line of least resistance, has a tendency to work on this tender material to such extent that serious caving may result, involving possible loss of casing seat and rather expensive cleaning out, or perhaps also expensive cementing, if such structure happens to carry water. (See illustration).

Limited experience and tests seem to indicate that sand stemming properly used will tend to reduce such hazards as are just referred to and will also tend to keep down expense, while increasing the yield.

It is desirable to remove all fluid from the hole, if that be practicable. However, if not practical, then sand stemming can still be made effective by confining the sand column below the casing seat and by placing an additional 10 ft. of broken brick on top of the sand. While with fluid in the hole there is more chance of damage to the pipe than without fluid, such danger can be minimized by filling the hole to overflowing (preferably with oil) so that the disruptive

While The Petroleum Engineer's general policy is to publish only original material, we are, because of the exceptional interest now being shown in sand tamped well shooting, making an exception in the case of this article which was extracted from a recently released booklet written by P. L. Lewis, manager of the Mid-Continent Division of American Glycerine Company. We are thankful to Mr. Lewis for permission to use his material, and to Mr. W. J. Cheley of the Zero Hour Torpedo Company, who brought it to our attention.

[1]U. S. Bureau of Mines Technical Paper No. 17, "The Effect of Stemming on the Efficiency of Explosives."

Sand Tamping
sives in Oil Well Shooting

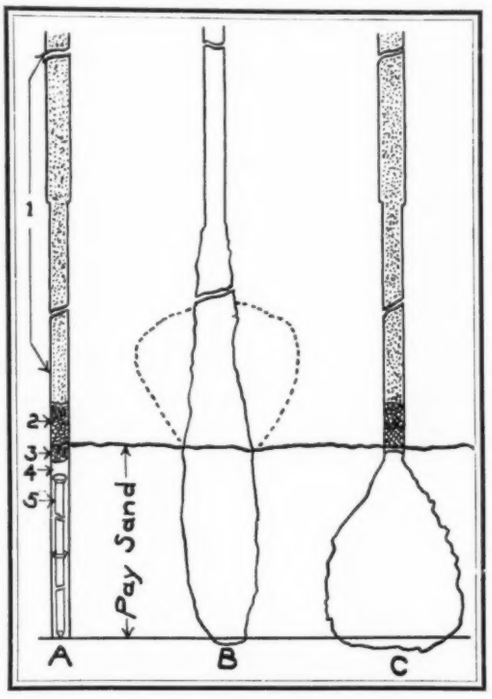
vibrations may be carried up the fluid column. This statement is based on the observed fact that, in a majority of cases where pipe is damaged with fluid in it, such damage occurs at the extreme bottom end, if close to the shot, or at a fluid level.

While there is no precedent to serve as a guide, it may be possible that in cases where there is high gas pressure and where the stemming material has a tendency to blow out, sand stemming can be used by "watering off" the gas pressure and proceeding as though there were no water in the hole, and then removing the water by bailing or swabbing—preferably by bailing, to avoid disturbing the sand—in which case it is imperative that there be placed on top of the sand stemming at least 10 ft. of broken brick or tile.

In preparing a "sand-tamped" shot, much annoyance and possible expense can be avoided by a properly organized plan of operation and avoidance of haste. Drilling, sand and measuring lines should be run before the shot, and lines flagged for bottom, top of pay and fluid level; and, if there be a liner in the hole, the shooter should be informed of its presence and position. The shooter should in all cases be correctly informed of any irregularities in the hole, such as location of known caves, sidetracked equipment, etc., so that he may be enabled to proceed without delay or undue hazard to get his shot set at the proper horizon.

A forked stick, brush, oakum, broken brick and sand in suitable quantity, or other "bridge" material should be available at the well before the shot and bomb are run so that it is possible to estimate properly the time required to place the shot, the bomb and the sand: to pull casing or perform other necessary operations and to set the bomb so as to allow ample time for safety and contingencies.

When all preliminary preparations are completed and required materials assembled, the first step in loading the hole is, of course, to run the shot; next is the preparation and placement of the bomb. Above the bomb, with a 2-ft. space for safety, the "bridge" is then set with the drilling tools or the bailer, tools being preferred because of their greater weight. If for any reason it is inadvisable to run either the tools or the bailer, a satisfactory bridge can be set by running a 10-qt. shell filled with sand and setting it on top of the bomb shell, and on top of this should be dropped a burlap sack weighted with cast iron or stone (a sash weight broken in half works nicely) and the weight tied tightly in place. When the "bridge" is set, the next step is to drop in the broken brick or stone, one piece at a time at 10-second intervals, or longer, depending upon size of the hole and density of the fluid, if any. The quantity of broken brick should be enough to fill at least 10 ft. of hole if there be sufficient space between the top of the shot and bottom of the casing. The number of feet of broken stone may be calculated on a basis of one foot of stone for each 10 ft. of open hole, with 20 ft. of stone as the maximum. After one foot of stone has been dropped, the shooter should run his cage on it to be certain that all pieces are reaching the top of the "bridge" and that they are not forming an obstruction somewhere in the hole. In holes of small diameter where fluid cannot be removed, it is well to avoid use of brick entirely if the first few give trouble. After all brick is dropped, the cage should again be run to make certain that all is well. If measurements check, then proceed immediately with sand. Sand should be poured into the hole through an improvised funnel, which can be made from any kind of available sheet metal. Before shoveling any sand into the hole, be sure to seal with burlap, or other suitable material, all annular spaces between outside strings of pipe, so as to avoid a "sand hitch."



"A" illustrates a sand tamped shot: (1) relative position of sand; (2) broken brick; (3) Oakum or brush packer; (4) air space; (5) torpedo

"B" illustrates the long slender type of cavity such as may reasonably be expected to result from a fluid tamped shot. Dotted line above pay sand indicates what may happen if wall of hole has caving tendencies.

"C" illustrates the pear-shaped cavity that usually results from sand tamped shot. As this result is obtained in quarry blasting practices, it is reasonable to assume that comparable results can be obtained in a well, and if obtained in a well, it is equally reasonable to assume that the energy developed is expended in a near-by horizontal place in the pay stratum.

There is little danger of bridging the hole with damp sand, even if there is fluid in the hole, if it be shoveled in, a half shovelful at a time, at the rate of 10 half-shovels per minute.

If measurements are deemed necessary during the sanding operation, such measurements should be made by means of a cage on a flagged torpedo or measuring line. Keep the cage in motion while hunting for marks on the measuring line. Do not run bailer or tools after sanding has started, on account of the chance that they may become sand-locked in the hole.

After sanding has been completed, observe carefully the volume of gas coming from the hole so that you may make comparison with the volume following the firing time. If there be any appreciable increase in gas volume, there is reasonable certainty that the shot has exploded, even though no explosion has been heard or jar felt at the surface, at the well. It happens occasionally that there is no sound or jar at the rig, though in the majority of such cases, the jar has been plainly felt as far away as two locations. This would seem to indicate that, because of the close confinement of the shot by sand-tamping, the force of the explosion had expended itself in a horizontal plane in the pay stratum, as would seem to be desirable.

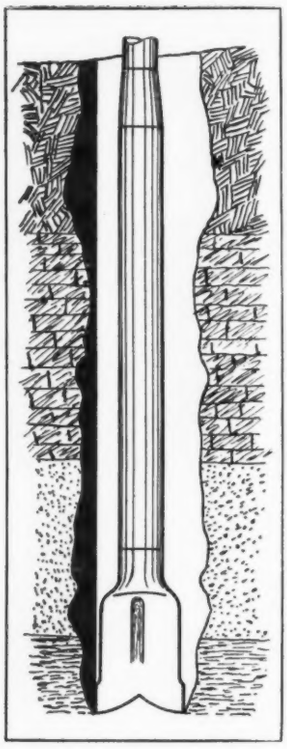


FIGURE 1

The result which the chemical aims to secure is shown on the left wall, and is contrasted with the broken irregular wall made by the bit as shown on right.

Chemically Treated Drilling Fluid

By WALLACE A. SAWDON

Petroleum Engineer, Los Angeles, Calif.

THE increased attention which the oil industry has paid to drilling mud during the past few years clearly indicates the importance of controlling the character of the circulating fluid. With the study of and experimental work on the mud itself and the use of weight material and other admixtures doing much to advance the science of drilling, it has been demonstrated that better fluids have played an important part in drilling operations and have frequently aided materially in the successful completion of wells. Meanwhile, chemical compounds have been developed with an aim to secure a complete control of the drilling mud under all conditions encountered; and the results obtained by the use of these chemicals under adverse conditions have indicated possibilities that are worthy of attention.

In applying chemicals for control of mud fluids, the objective must naturally be the ideal drilling fluid. This ideal is just as naturally different for different wells and for different conditions. If the formation is one with cavities that take the mud as fast as it is pumped in, the best fluid to use certainly does not possess the same characteristics as one that would be ideal for drilling through a tight formation into a high pressure producing zone. The chemical to be introduced, therefore, would not be identical for both conditions; it would have to be of a character and amount that would best meet the conditions actually encountered.

Wells, especially the deep wells of the present day, frequently present a number of widely different problems during the course of their drilling which can be assisted, or even completely overcome, by the use of proper drilling fluid. Control of the fluid, however, is the necessary factor and its character must often be changed as the well progresses. When chemicals are used for this control, they must give the mud fluid, through their reactions, the properties that are most desirable to meet the particular conditions encountered. No one formula can do this and the proper one, together with its proper amount, must be determined before its mixture with the mud is effected. Prevention of troubles rather than extensive repair work should naturally be the aim of chemically controlled drilling fluid. Such a fluid must therefore include all the characteristics that are generally demanded as a requisite. It must provide for the efficient return of the cuttings to the surface; it must seal the walls to prevent caving and the loss of the mud through cavities and porous formations; it must lubricate the hole to reduce friction on the drill pipe and to cool the bit; it must overcome high gas and water pressures when encountered; and its viscosity must be kept low enough to be handled easily by the pump.

These properties are preventive as well as beneficial and, when the mud is properly controlled, they will do much to eliminate caving formations, blow-outs, loss of circulation, fishing jobs and frozen pipe as well as aid materially in keeping the hole straight. There are times, however, when formations encountered require particular treatment and the drilling fluid must be given properties that are peculiarly adapted to meet specific conditions. When chemicals are used for this purpose, predetermined formulas and amounts must be applied for these particular cases; and proper supervision should be provided to make results most effective.

The chemicals as used up to the present time have been provided in both liquid and powdered form. Probably 50 different formulas have been used under various circumstances but from eight to ten of these will probably cover the majority of cases encountered. This would seem to forecast a confusion in application; but with a knowledge of the mud and water to be used together with other data which are generally available, the proper chemical and its amount are readily determined. When supplied in powdered form, it is usually introduced with a mixer; when liquid, its flow in the proper amount can be regulated through a valve or ordinary hydrant.

The chief reaction of many of these chemical formulas is a crystallization of the fluid on the walls of the hole. This crystallization takes place slowly, with the time governed by conditions and secured by the specific formula and the amount used. The action, of course, must be kept slow enough to prevent friction on the drill pipe and the result which the chemical should aim to secure is shown on the left side of the drill stem in Figure 1. This is contrasted with the broken, irregular wall made by the bit as shown on the right of the stem in the same drawing. The object is, of course, to fill, bond and seal all cracks and cavities as the well is drilled through the different formations. With this accomplished, the wall would be reinforced and caving prevented. In heaving formations the stratum will be solidified by such action and drilling can proceed without interruption.

The chemicals now being used also aim to stimulate the colloidal properties of the mud fluid. Three sacks of one formula in powdered form were used in 600 feet of a 27-inch hole and made the fluid as thick as could be handled. Three hundred pounds used with 50 barrels of mud fluid in another well was too much and had to be thinned out. The amount, however, is governed by conditions and is determined when the chemical formula is designated.

In drilling into high pressure zones with chemically treated mud, it has been found that great weight is not always necessary. In a General Petroleum well in the Lost Hills field in California the drillers were using a 110-pound mud until chemicals were introduced. The weight was then cut down to 80 pounds and the work was able to proceed with this

Chemical compounds mixed with circulating muds are used to advantage in California to overcome many drilling difficulties » » » »

lighter mud. The chemically treated fluid in this case evidently overcame the pressure and gas-cutting without necessitating the use of heavy mud. The introduction of chemicals can be made, however, with heavily weighted mud and beneficial reactions should be secured with heavy mud as well as with lighter fluid.

The crystallized walls as built up by chemicals introduced into the mud fluid will probably attain a hardness just a little greater than that of plaster of Paris. Here again the character of the chemical will have an influence. In regaining lost circulation, however, the solid formed by the chemical reaction should be about that hard and must, of course, be impervious to moisture, and consequently, to the circulating fluid in order to keep it from going into the formation.

An interesting case of recovering lost circulation with these chemicals is that of the Standard Oil Company's well, Mascot No. 1, in the Midway field, California. A string of 9-in. casing had been set at 6350 feet and drilling resumed with a 7⅞-in. open hole when circulation was lost. Before chemically treated mud was introduced, 62,000 pounds of admixture, 580 tons of dry mud, 650 sacks of cement, 660 sacks of cottonseed hulls, 781 sacks of sawdust and 23 bales of hay had been used.

The chemicals decided upon for the job were in both liquid and powdered form and the amount used was approximately four pounds per barrel of mud fluid. An estimate was first made of the total amount of liquid it would take to fill the hole to the surface if none of it was lost; and a little more than that amount of mud fluid was treated. This treated mud fluid was then pumped in and allowed to stand for a few days. Drilling was then resumed and circulation recovered.

In an extreme case of this kind, the chemically treated fluid evidently goes some distance into the crevices, or whatever the outlet may be, and starts crystallization some distance from the wall of the hole. The solids so formed build up and slowly close the opening, with other solids forming behind them to make an impervious filler that confines the liquid to the well.

While the adaptability of these chemicals for recovering lost circulation might seem particularly evident due to their reaction in changing a part of the liquid mud into solids, probably one of the most difficult repair jobs made with chemically treated mud was in excluding heaving shale from a hole. This job was supervised by Albert J. Rainey, a chemical engineer of Los Angeles.

The well was Standard Oil Company of California well, Elk Hills No. 25, in which the 9-inch casing had been cemented at about 6000 feet. Drilling below this point, a shale was encountered, which had a high gypsum content that would disintegrate or melt when it came into contact with water. The hole could be made but when the tools were pulled, the shale would heave in and fill it back to the casing.

One length of drill pipe 425 feet long was first lost when the well reached a depth of about 6645 feet. Attempts were made to sidetrack and before the application of chemicals was tried there were four such sections of drill pipe, one core barrel and an overshot in the hole, as indicated in the drawing, Fig. 2.

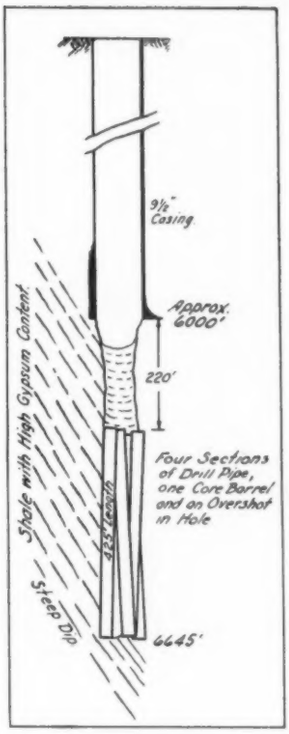


FIGURE 2

Heaving shale was successfully kept out of this hole by the use of chemically treated mud fluid, which permitted deeper drilling

All the old mud was first thrown away and a supply of unused, clean mud prepared when the chemical treatment of the well was started. A penetrating chemical was first used with the mud, which was circulated for 24 hours to insure its uniformity. The hole was then slowly cleaned down to the fish with this. The fish itself was not touched and the drill pipe was raised about 25 feet, where the fluid was circulated for 72 hours.

The fluid here used was a light mud of from 70 to 72 pounds per cu. ft. treated with about 2½ to 3 gallons of chemical per barrel. It was tested continuously and kept uniform and it is believed it penetrated for 400 or 500 feet from the hole.

At the end of the 72 hours, the pipe was pulled back to the bottom of the casing and a crystallizing chemical was mixed with the mud. This fluid was then circulated for two or three days with the pipe being lowered and raised continually between the bottom of the casing and the top of the fish at a speed of 10 ft. per hour.

It was then felt that the walls of the hole were sufficiently reinforced with the crystallized solids to start sidetracking the fish. This was done for five feet and the new walls were solidified by circulating back and forth for three days. The sidetrack was now considered started in good condition and the tools were let down at regular drilling speed.

Drilling continued with the chemically treated mud. Bad pockets of shale were encountered at times, however, and when such were penetrated, the tools were backed up, additional chemical was added and the wall of the hole thus reinforced before going on.

Large cavities in wells have been filled with chemically treated mud by the process of circulating over a period of time with the pipe slowly raised and lowered until the hole was confined within walls of approximately the diameter of the bit gauge. The ordinary cavities can be taken care of in this manner, but some have to be given individual attention. One drilled with cable tools in the Turner Valley field in Canada required the use of tubular shells which were filled with chemically treated mud fluid lowered into position, where the fluid was released.

River Crossings on Burmah Pipe Line

Seasonal high water has necessitated many overhead crossings

By WARREN L. BAKER

Bridge over Belin Chaung. The distance between derricks is 420 ft. in length

ONE of the oldest oil pipe line systems outside of the United States is that of the Burmah Oil Company in Burmah. It was laid in 1908-09 and extends from Nyaunghla in Upper Burmah to the company's Syriam refinery in Lower Burmah, a distance of some 275 miles. Nyaunghla is about five miles from the well-known Yenangyaung field and has a large tank farm. Syriam refinery, the terminal of the line, situated on the east bank of the Pegu River, near the confluence of the latter with the Rangoon River, is about 15 miles to the east of Rangoon, the chief seaport of Burmah, and lying on the east bank of the Rangoon River 20 miles from the coast The line, 10-in. in diameter and with screwed joints, was laid when few engineering data were available on long-distance transportation of crude oil by pipe lines of large diameter.

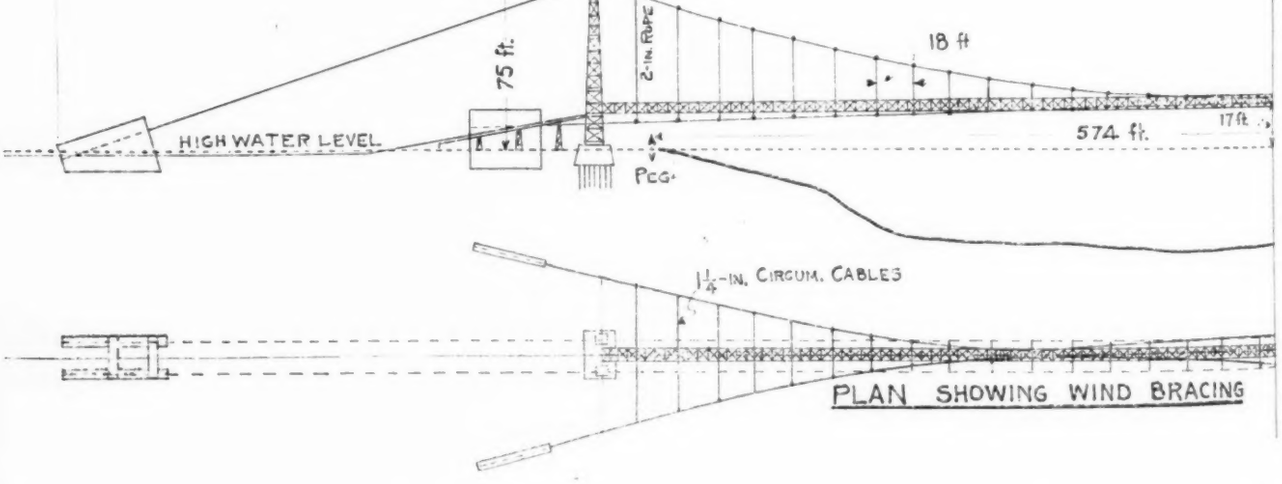
Since the line has been in operation much has been learned by Burmah Oil Company engineers about the transportation of crude oil by pipe line in the tropics. Because of the great extremes of temperature, both daily and seasonal, the heat and high humidity that are encountered, the conditions are unusually severe. The upper end of the line, from Nyaunghla to Prome, practically parallels the Irrawaddy River. From Prome, the line parallels the railroad almost to Rangoon. On the upper end of the line the topography is quite rugged in places and the climate, though hot, is relatively dry. On the lower end of the line the country is low-lying and marshy, and during the rainy season, from May to September, the rainfall is heavy, which, with the extreme heat, produces conditions of high humidity.

In places, the country traversed by the line is cut up by small streams, many of which during the dry seasons carry no water but, during the rainy season, become raging torrents. Many of the creeks change their course from year to year. When this happens, the banks are washed out and the pipe is left high and dry. In the early days this was a source of trouble during the rainy season, for the line occasionally would break or serious leaks would result.

A brief description of some of the pipe line creek crossings may be of interest to readers in the United States. Many of these crossings in the early days were laid deep in the bed of the creek. This method in many cases was soon found to be inadequate to meet the conditions. Most of the crossings that gave trouble in the early days are now carried overhead.

Accompanying this article is a sketch of a pipe-line bridge that was laid across the Pazundaung creek as far back as 1909. As the creek empties into the Rangoon River close to where

Suspension bridge carrying pipe line over Pazdundaung Creek,



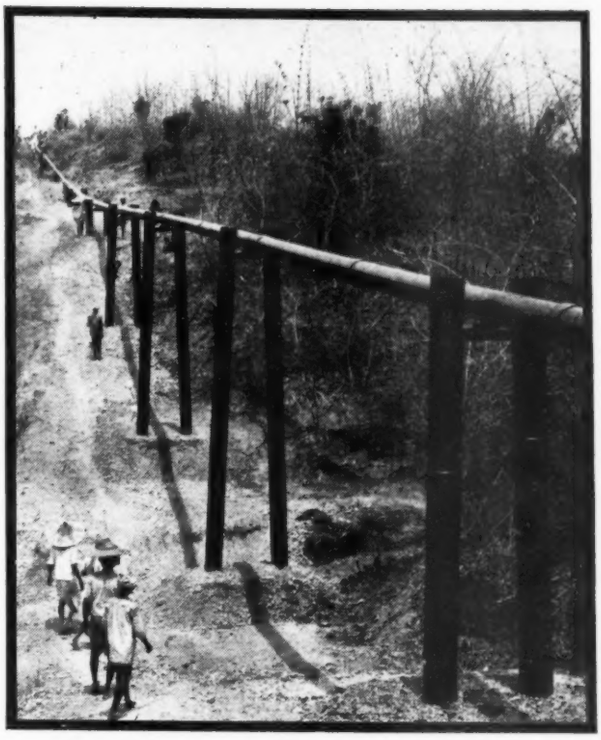
Ravages of climate sucessfully combated by systematic upkeep

the line crosses, it is tidal at this point, having a rise and fall of more than 30 ft. at the pipe-line crossing. The banks of the creek are composed of a soft treacherous mud. To prevent erosion many methods were tried, including the dumping of scrap material, and piling with 10-in. pipe, but none of these was satisfactory. Finally a scheme was hit upon that has been found most effective—the planting of mangrove scrubs well down to the low-water level.

The bridge has a span of 630 ft. between derricks and carries on rollers twin 10-in. lines, which are connected to the line on the bank with 10-in. flexible spring pipes. There is a 24-in. foot path on either side of the twin lines. These lines have been in use since 1909, but are still in excellent condition, with no sign of external corrosion, which fact is due chiefly to the system of upkeep that is followed. The pipe is cleaned and treated with a bitumen solution yearly. Cables and all anchorages are thoroughly examined, cleaned and greased with a special grease. About every three years the structure is thoroughly scraped and then painted.

This is only one of the bridges carrying the pipe line over creeks and rivers. Since the line has been laid a progressive program has been carried on. Other important structures have been completed, one of which is shown in the accompanying illustrations. This one is known as the Belin bridge. It has a 420-ft. span from center to center of derricks, the height of the latter being 49 feet. This bridge carries one single 10-in. welded line, which is joined to the main line section by a special expansion joint with a pull-out preventor attached. The back anchorages were cored so that a line could be carried through the blocks, thus saving any acute bends and also adding to the weight of the anchorages. There has also been built a number of bridges, the respective spans of which range from 150 ft. to 240 ft. in length. An interesting feature of this type of bridge is that old material has been utilized, such as 10-in. pipe that has been condemned for pipe line service. It is welded together on the site and made into derricks. Old drilling cables classed as unfit for further field service on wells have been used to carry the line over the crossing. Several deep rivers have been bridged by erecting supports from old material, and by so doing considerable footage of new pipe has been saved. In addition,

Rangoon, Burmah. This bridge has been in service since 1909

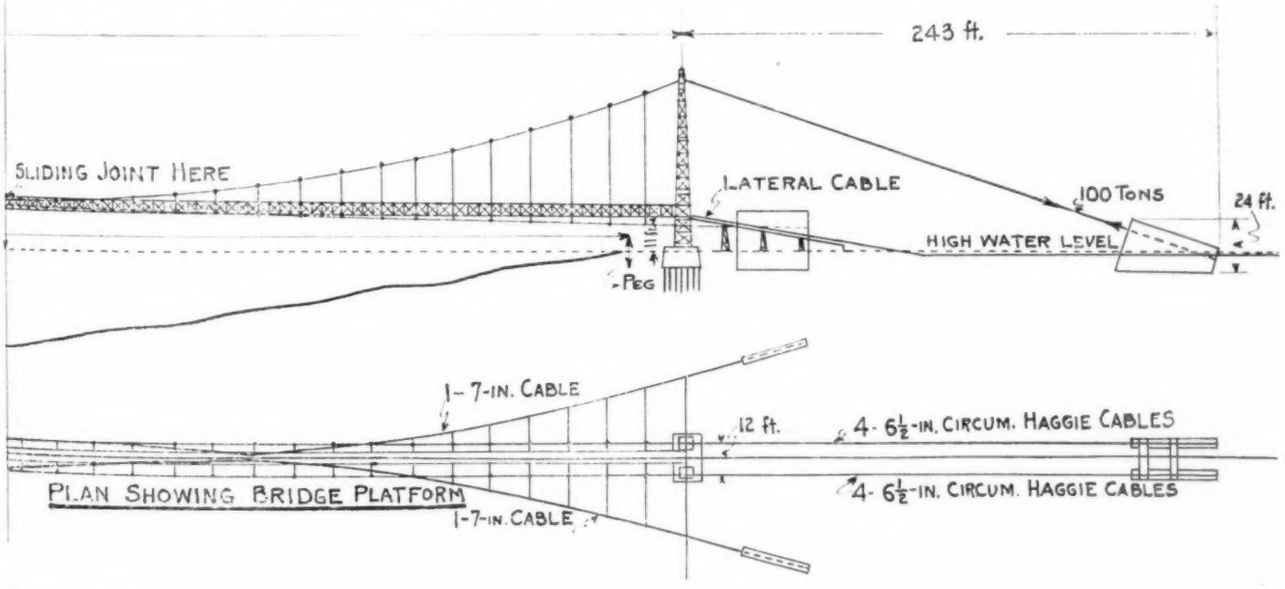


Avoiding pipe-bends by carrying pipe across dips on supports

from 80 to 90 per cent of fire bends previously found necessary at those creek crossings have been eliminated.

A bridge of 400-ft. span over Bwetgyi Chaung was built by the Public Works Department of Burmah. This creek, which is a tributary of the Irrawaddy River, has always been a source of grave worry owing to changing its course each rainy season. In doing this the heavy scouring action would erode the channel to a depth of from 12 to 20 ft., depending on the height of the Irrawaddy River. Through the Public Works Department, Burmah, permission was granted for the erection of special brackets on the under center of the bridge girders to carry the pipe across the creek. The pipe was welded and tested to a pressure of 600 lb. per sq. inch. This line has been in commission since early in 1930.

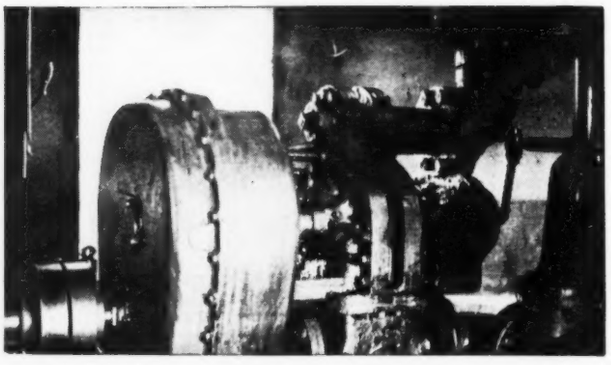
It is found that pipe exposed and not in contact with the soil has never shown any external corrosion, so when possible the pipe is laid on supports where corrosive soil conditions are found.



Rotary Pumps for Handling Acid Sludge

Pumps Selected Should Be Able to Operate at a Pressure Much Higher Than Normal Working Pressures

By H. A. ROGERS, Engineer



An acid sludge pumping unit

REFINERIES manufacturing lubricating oil make a considerable quantity of acid sludge, and as it is a waste product, some disposal of it must be made. Many refineries are now disposing of their acid sludge by burning it under their boilers. It is mixed with approximately 50 per cent of fuel oil and circulated by means of pumps to the burners.

After very thorough tests, which followed a great deal of experimental work, involving different sizes of rotary pumps working at various capacities and pressures, a rotary pump to handle acid sludge has been designed and perfected that will operate 24 hours a day with no more attention than pumps in any other service. This experimental work had to do chiefly with a study of the metal parts of the pump that come in contact with the acid sludge, namely, the pump head, rotors, and shafts. Various kinds of metal alloys have been tried out until satisfactory performance has been attained. In acid sludge pumps, considerable trouble is often experienced on account of leakage through the packing glands. This problem was thoroughly studied. Stuffing boxes were properly proportioned to prevent leakage, and various types of packing were tested until trouble from leakage was entirely eliminated.

Each acid sludge pump installation is a definite problem in itself, for the capacity of the pump, the discharge pressure, the pumping temperature, and the viscosity and other qualities of the acid sludge vary in each installation.

The pump handling the sludge usually circulates a much larger quantity of sludge than the amount burned. A rotary pump properly designed and of the right capacity is well adapted for this type of pumping. If driven by a motor or a turbine, the driving and the driven unit make a compact installation of the simplest type.

Rotary pumps in the smaller sizes can be run at higher speeds than the larger units. If the quantity of sludge to be disposed of is very small, the rotary pump can be run at 860 r.p.m. and be direct-connected to a motor of that speed. For handling large quantities of sludge, however, the speed of the pump should be reduced, using either a slow-speed motor, a reduction gear built into the pump, or a steam turbine with a built-in reduction gear. Capacities and pressures vary considerably in different sludge disposal systems, and the pumps selected should be able to operate at a pressure much higher than the normal working pressure, for if the pump is started up when the sludge in the line is cold, the pressure will rise quickly to beyond the working pressure because of the additional pipe friction that must be overcome to put the sludge in motion. The selection of the driver should also be based on these overload starting conditions and be amply powered to meet them.

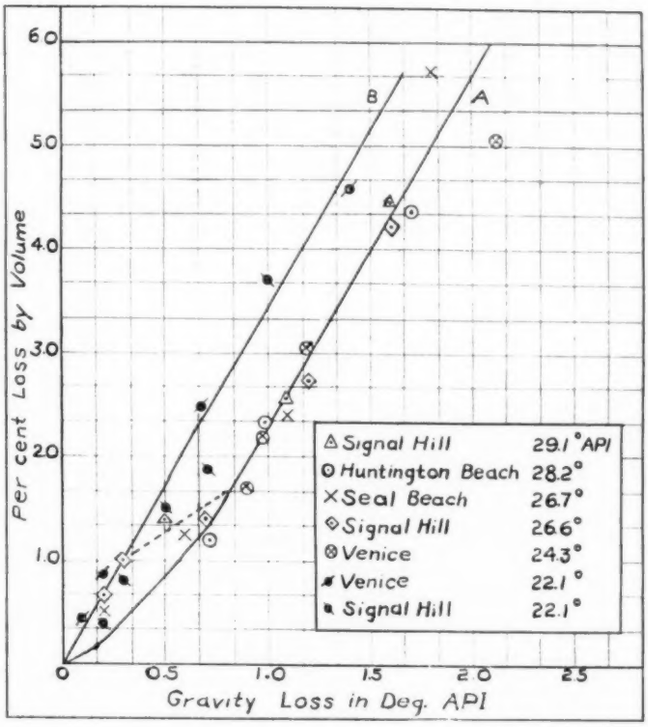
Besides a weak solution of sulphuric acid, acid sludge contains a certain amount of abrasive particles, and is a rather viscous fluid even under the temperatures at which the pump operates. On this account, some type of positive displacement must be used. As the sludge is to be burned, there should be no pulsations at the burner tip. The pressure should be held constant to give an even flame in the boiler; an especially desirable feature in this service.

As this is in an important operation in a refinery, a stand-by unit should be available in case anything happens to the pump in service. The installation of a sludge pump should be carefully made. Pipe strains should be eliminated so that there will be no tendency to pull the pump out of line, and the unit should be carefully aligned. Provided the pump has been properly selected, as regards capacity, pressure, and speed, and is constructed of right materials, operation will be entirely satisfactory.

Volume Losses When Handling Hot Crude Oil

By WILLIAM WOELFLIN

Research Engineer, Petroleum Rectifying Company of California



Relation between gravity loss in deg. A.P.I. and per cent loss by volume is shown in this chart

IN the January, 1933, issue of *The Petroleum Engineer* results of an investigation were given that showed the gravity loss when handling hot oil. This gravity loss varied from zero to as high as 2.2 deg. A.P.I., depending on the gravity of the crude oil, the temperature, and manner in which the hot oil entered the tank. The greatest loss occurred when oil at a high temperature entered a tank through an ell at an open manhole on top of the tank, and the least loss occurred when the oil was cooled and entered a vapor-tight tank through a connection near the bottom of the tank.

The loss as reported in this previous article was expressed as a gravity loss only, but there is, however, a loss in the volume as well as a loss in the gravity of the crude oil.

In order to determine what a 1-deg. A.P.I. gravity loss would mean in the volume of the crude, a series of tests were made to correlate the gravity loss in deg. A.P.I. with the per cent volume loss.

These tests were made by determining the gravity and volume of a sample of crude oil, before and after it had been heated to drive off a part of the fractions lower than boiling point. The volume of oil in each case was determined by first obtaining the weight of the oil, and dividing the weight by the specific gravity. From the volume of crude oil before and after heating, the per cent loss by volume was calculated. It is assumed that the light fractions lost by evaporation in the laboratory by heating the crude oil are approximately the same as the light fractions lost when evaporation occurs in the field, with the result that the "volume-gravity" relationship would be the same in each case. The volume loss reported in this article refers to the loss expressed as a per cent of the original volume of crude oil.

The per cent volume losses were determined by four different points on each sample by heating to a higher temperature in each succeeding determination to drive off a larger quantity of light fractions. These four points served to construct a curve to show the per cent volume loss and the loss in degrees A.P.I. for that particular oil.

When the results from the seven oils tested are all plotted on the same sheet, as shown on the accompanying graph, two curves can be drawn through the points. Curve A is drawn through points that represent the lighter gravity crudes, that is, those crudes from 24.3 deg. A.P.I. to 29.1 deg. A.P.I., from Huntington Beach, Seal Beach, Signal Hill and Venice. Curve B is drawn through the lower gravity crudes (22.1 deg. A.P.I.) from Signal Hill and Venice.

It must be noted that the lower points from the Signal Hill and Seal Beach oils fall more nearly on Curve B (low gravity curve) than on Curve A (high gravity curve). If the curve were drawn particularly for the Signal Hill and Seal Beach oils, it would start as Curve B and cross over to Curve A, following approximately the dotted line between the two curves. The shape of the curves will, of course, depend on the kind and amount of light fractions driven off by heating. Since these fractions are not the same for all crude oils, the curves for any particular crude will vary from the Curves A and B.

Based on the above curves the following approximate relationship between gravity loss and volume loss can be obtained.

Loss in deg. A.P.I.	Per Cent Volume Loss	
	22-deg. A.P.I. Crude	24-29-deg. A.P.I. Crude
0.5	1.7%	0.9%
1.0	3.4%	2.2%
1.5	5.1%	3.9%
2.0		5.6%

The volume loss represented by the 0.5 deg. A.P.I. loss in gravity of the 22-deg. oil is approximately twice as great as the volume loss represented by the same loss of gravity from the higher gravity oil. However, a gravity loss of 0.5 deg. A.P.I., which represents a volume loss of 1.7 per cent, would be a large loss for a 22-deg. A. P. I. oil, while the same gravity loss would be only a nominal loss for a lighter gravity crude, and would represent a volume loss of 0.9 per cent.

Although all the above data were obtained from tests on California oils, similar tests were made several years ago in the Mid-Continent on Smackover oil by the Tretolite Company. These latter tests show a volume loss of 2.8 per cent for 1-deg. A.P.I. gravity loss on an average production of 21-deg. A.P.I. Smackover oil. These figures are in line with the data on California oils, and indicate that these data would probably apply to a large class of crude oils.

These curves and data can only be considered as approximations and are presented to give some idea of the magnitude of the volume losses that are represented by the gravity losses shown in the preceding article.

ARTICLE 1

This is the first of a series of articles prepared to assist in determining the proper size and type of unit for use on wells of various depths and pumping conditions. When complete, this series will form a valuable reference and guide to the solution of many problems of the type commonly encountered in wells today. Information and engineering data from authoritative sources are gathered together in handy form for application to the solution of problems as they are met with in the field. How these data enter into pumping problems is discussed at some length by the author, who has given this subject intensive study.

EDITOR.

Solving Well-Pumping Equipment Problems

By HYMAN LEDEEN

Engineer-in-Charge, Western Division,
The Falk Corporation, Milwaukee, Wis.

FOR the present at least, it seems that it is no longer possible to increase profits by producing more oil. It is possible, however, to increase profits by producing oil more economically and more efficiently. The question now is not how many barrels per day, but how many barrels per dollar. Produce more barrels per dollar and you reduce the unit cost of production.

Pumping equipment properly chosen to meet the specific well conditions can be the means of effecting great economies that will result in a low unit pumping cost. If the specific well conditions are known within a reasonable degree of accuracy, it is possible, by the intelligent use of available engineering data, to make a wise selection of pumping equipment that will successfully accomplish the desired end. There are many technical angles to the problem of pumping a well, and the deeper the well the more involved the problem becomes. A problem in well-pumping properly attacked is half solved. It is the purpose in presenting this series of articles to bring before the reader many available but widely scattered engineering data that bear on the problem of well-pumping and to discuss their application in the practical solution of well-pumping problems. Many factors that are negligible when considering shallow wells must be taken into account and be given due weight when considering deep wells.

The Pump

Oil is produced from the well in three principal ways: natural flow, gas-lift and pumping.

Natural flow, obviously the cheapest method of production, is limited in the length of time that its use is possible, by physical conditions in the well. The reservoir energy begins to diminish from the moment the well is brought in. Sooner or later, the natural reservoir energy become insufficient to force the oil to the surface, and auxiliary means must be used for production. Gas-lift is then commonly adopted to decrease the weight of the volume of fluid and start the well flowing. This method of production is used until its cost reaches a prohibitive point. It is then that the pump is resorted to as the most economical means of producing oil.

The amount of fluid that can be raised in any given unit of time will depend on the diameter of the plunger, the length of its stroke, and the number of upward strokes that it makes. The efficiency with which the fluid will be raised depends on the wise or unwise selection of each of these items. Various available pump sizes are shown in Table 1.

Pump Sizes and Plunger Diameters

Besides these shown in Table 1, other sizes, too numerous to mention, are also available, and new sizes and types are being developed. There is, however, an effort being made to standardize and reduce the number of sizes.

Sucker rods are available in three sizes: ⅝-in., ¾-in., and ⅞-in. diameter.

Pumping strokes for 6-in. rig irons, according to A.P.I. standards, are as given in Table 2.

TABLE 1

Pump Sizes and Plunger Diameters

Size Tubing (Minimum)	Size Pump (Nominal)	Size Plunger (Actual)
2 in.	1 in. Liner	*1 in.
2 in.	1 1/16 in. Liner	1 1/16 in.
2 in.	2 in. Insert	1 1/2 in.
2 in.	2 in. Liner	1 3/4 in.
2 1/2 in.	1 in. Liner	*1 in.
2 1/2 in.	1 1/16 in. Liner	1 1/16 in.
2 1/2 in.	2 1/2 in. Insert	1 25/32 in.
2 1/2 in.	2 1/2 in. Insert	1 15/16 in.
2 1/2 in.	2 1/2 in. Liner	2 1/4 in.
3 in.	1 in. Liner	*1 in.
3 in.	1 1/16 in. Liner	1 1/16 in.
3 in.	3 in. Insert	2 1/4 in.
3 in.	3 in. Insert	2 7/16 in.
3 in.	3 in. Liner	2 3/4 in.
4 in.	4 in. Liner	3 3/4 in.

*Not Standard.

TABLE 2

Pumping Strokes (A.P.I. for 6-in. Rig Irons)

Position of Hole in Crank	Center of Crank to Center of Pin	Polished Rod Stroke
1st Hole	12 in.	24 in.
2nd Hole	17 in.	34 in.
3rd Hole	22 in.	44 in.
4th Hole	27 in.	54 in.
5th Hole	32 in.	64 in.
6th Hole	37 in.	74 in.

TABLE 3

Areas of Cross-Sections

⅝ in. Rod	0.3068 sq. in.	1¼ in. Tubing	0.6685 sq. in.
¾ in Rod.	0.4418 sq. in.	1½ in. Tubing	0.7995 sq. in.
⅞ in. Rod	0.6013 sq. in.	2 in. Tubing	1.304 sq. in.
		2½ in. Tubing	1.812 sq. in.
		3 in. Tubing	2.590 sq. in.

TABLE 4

Coefficients for Computing Theoretical Loss of Stroke Due to Rod and Tubing Stretch (By Method 2)
¾-in. Rods and Negligible Acceleration

Gravity of Fluid Deg. A.P.I.	2 in. Tubing		2½ in. Tubing			3 in. Tubing			Sp. Gr.	Ratio to 30 deg. A.P.I.
	1½ in. Diam. Pump	1¾ in. Diam. Pump	1²⁵⁄₃₂ in. Diam. Pump	1¹⁵⁄₁₆ in. Diam. Pump	2¼ in. Diam. Pump	2¼ in. Diam. Pump	2⁷⁄₁₆ in. Diam. Pump	2¾ in. Diam. Pump		
10	0.958	1.305	1.255	1.486	2.004	1.886	2.213	2.817	1.000	1.142
12	0.945	1.287	1.238	1.466	1.976	1.860	2.183	2.779	.986	1.129
14	0.932	1.269	1.221	1.445	1.949	1.834	2.153	2.740	.972	1.111
16	0.919	1.251	1.204	1.425	1.922	1.809	2.123	2.702	.959	1.097
18	0.907	1.235	1.188	1.406	1.897	1.785	2.095	2.666	.946	1.082
20	0.895	1.218	1.172	1.388	1.871	1.761	2.067	2.631	.933	1.068
22	0.883	1.202	1.157	1.369	1.846	1.737	2.039	2.595	.921	1.052
24	0.872	1.187	1.142	1.351	1.822	1.715	2.013	2.562	.909	1.039
26	0.861	1.172	1.128	1.335	1.801	1.695	1.989	2.531	.897	1.026
28	0.850	1.157	1.113	1.318	1.777	1.672	1.963	2.498	.886	1.013
30	0.840	1.143	1.100	1.302	1.755	1.652	1.939	2.468	.875	1.000
32	0.829	1.129	1.086	1.286	1.734	1.632	1.915	2.437	.864	.989
34	0.820	1.116	1.074	1.271	1.714	1.613	1.893	2.409	.854	.977
36	0.809	1.102	1.060	1.255	1.692	1.592	1.869	2.379	.843	.965
38	0.800	1.089	1.048	1.240	1.672	1.574	1.847	2.351	.833	.952
40	0.791	1.077	1.036	1.226	1.654	1.557	1.827	2.325	.824	.943
42	0.782	1.064	1.024	1.212	1.634	1.538	1.805	2.297	.814	.931
44	0.773	1.052	1.012	1.198	1.616	1.521	1.785	2.272	.805	.921
46	0.764	1.040	1.001	1.185	1.598	1.504	1.765	2.246	.796	.910
48	0.756	1.029	0.990	1.171	1.580	1.487	1.745	2.221	.787	.900
50	0.747	1.017	0.978	1.158	1.562	1.470	1.725	2.195	.778	.890

From: "High Volumetric Efficiency in Oil Well Pumping and Its Practical Results", by Hallan N. Marsh, before A. P. I., June, 1931.

TABLE 5

Stretch of Rods and Tubing (= Loss of Stroke) for Wells of Different Depths and Pumps
30 deg. A.P.I. Gravity Oil or Equivalent. Stretch in Inches

Depth of Well in Ft.	2 in. Tubing—¾ in. Rods			2½ in. Tubing—¾ in. Rods				3 in. Tubing—¾ in. Rods			4 in. Tubing ¾ in. Rods
	1¹⁄₁₆ in. Plunger	1½ in. Plunger	1¾ in. Plunger	1¹⁄₁₆ in. Plunger	1²⁵⁄₃₂ in. Plunger	1¹⁵⁄₁₆ in. Plunger	2¼ in. Plunger	2¼ in. Plunger	2⁷⁄₁₆ in. Plunger	2¾ in. Plunger	3¾ in. Plunger
1000	0.421	0.84	1.143	0.391	1.100	1.302	1.755	1.652	1.939	2.468	3.340
1500	0.95	2.0	2.6	0.9	2.5	3.0	4.0	3.7	4.4	5.6	7.5
2000	1.7	3.4	4.6	1.6	4.4	5.2	7.0	6.6	7.7	9.8	13.0
2500	2.6	5.2	7.2	2.4	6.9	8.1	11.0	10.3	12.1	15.4	21.0
3000	3.8	7.6	10.3	3.5	9.9	11.7	15.8	14.9	17.4	22.2	30.0
3500	5.2	10.4	14.0	4.8	13.5	16.0	21.4	20.4	23.7	30.3	40.0
4000	6.8	13.6	18.3	6.3	17.6	20.8	28.0	26.5	31.0	39.5	53.0
4500	8.5	17.0	23.2	7.9	22.3	26.4	35.5	33.5	39.2	50.0	67.0
5000	10.5	21.0	28.6	9.8	27.5	32.6	43.9	41.4	48.5	61.8	84.0
6000	15.2	30.4	41.2	14.1	39.6	46.9	63.1	59.5	69.6	89.0	120.0
7000	21.0	41.0	56.0	19.0	54.0	64.0	86.0	81.0	95.0	121.0	163.0
8000	27.0	54.0	73.0	25.0	70.0	83.0	112.0	106.0	124.0	158.0	214.0
10000	42.0	84.0	114.0	39.0	110.0	130.0	175.0	165.0	194.0	247.0	334.0

Pumping Strokes

Many wells will be found pumping with other than A.P.I. strokes, and among those noted are: 20-in., 22-in., 27-in., 30-in., 32-in., 36-in., 40-in., 42-in., 48-in., 52-in., 56-in., 62-in., and 72-in.

Pumping speeds have, in the past, ranged from 20 to 30 strokes per minute (s.p.m.). Recently, however, much has been accomplished with slower pumping speeds. As a result, speeds as low as ¾ s.p.m. are in use.

Plunger diameter is determined to a large extent by the depth of the well and the length of the stroke. It is dependent on the stretch in the rods and tubing due to the weight of the column of oil being lifted.

Marsh[1] gives a formula for the stretch in rods and tubing from which

$$e = ce\left(\frac{L}{1000}\right)^2$$

where:

e = the stretch of rods and tubing due to weight of oil, or, the loss of effective stroke due to this stretch
L = depth of well in feet
ce = coefficient of stretch

$$ce = \left[\frac{12\times 1000^2 \times Ap \times Pp}{E}\left(\frac{1}{Ar} + \frac{1}{At}\right)\right]$$

Ap = total area of plunger in sq. inches
Pp = pressure on plunger (weight of oil, when no gas) in lb. per sq. in. per ft. of depth
Ar = cross-sectional area of sucker rod in sq. inches
At = cross-sectional area of metal in tubing in sq. inches
E = modulus of elasticity in lb. per sq. in. = (29,000,000 — 30,000,000).

Marsh also gives Table 4 of coefficients for certain common sizes of tubing and pumps, using ¾-in. sucker rods, as computed in his formula.

Table 4 and the formula are based on the following assumptions: (a) no acceleration, (b) no friction, (c) liquid level in casing at the pump, (d) no gas in the tubing, (e) rods straight. These assumptions are not always correct, but it is possible to make allowance for some of the items by varying others.

For example, on a comparatively straight hole 3500 ft. deep, pumping 30-deg. A.P.I. oil with 2½-in. pump and 2¼-in. plunger, ¾-in. rods and operated at slow speed, neglecting acceleration and with some gas in the tubing, the stretch in the rods can be computed as follows: assum-

[1] "High Volumetric Efficiency in Oil Well Pumping," by Hallan N. Marsh, a paper delivered before the A.P.I., June, 1931.

TABLE 6

Limitation of Plunger Diameter Due to Rod Stretch

For 10,000 ft. the maximum possible size of Plunger is 1¼ in. Diam.
For 8,000 ft. the maximum possible size of Plunger is 1 25/32 in. Diam.
For 7,000 ft. the maximum possible size of Plunger is 1 15/16 in. Diam.
For 6,000 ft. the maximum possible size of Plunger is 2 7/16 in. Diam.
For 5,000 ft. the maximum possible size of Plunger is 2¾ in. Diam.
For 4,500 ft. the maximum possible size of Plunger is 3¾ in. Diam.

TABLE 7

Standard Plunger Diameter for Maximum Production per Stroke

Depth of Well in Ft.	LENGTH OF STROKE					
	24 in.	34 in.	44 in.	54 in.	64 in.	74 in.
1000						
1500						
2000	3¾					
2500	2 7/16	2¾	3¾			
3000	1¾	2¼	2¾	3¾	3¾	
	1 15/16	2 7/16				
3500	1½	1 15/16	2¼	2¾	2¾	3¾
	1¾		2 7/16			
	1 25/32					
4000	1½	1¾	1 15/16	2¼	2 7/16	2¾
		1 25/32				
4500	1 1/16	1½	1¾	1 15/16	2¼	2¼
			1 25/32			
5000	1 1/16	1 1/16	1½	1¾	1 15/16	1 15/16
				1 25/32		
6000		1 1/16	1 1/16	1½	1½	1¾
						1 25/32
7000				1 1/16	1 1/16	1½
8000					1 1/16	1 1/16
10000						1 1/16

In the upper right corner of this table no values are given because standard plungers large enough in diameter are not available. If maximum production per stroke must be obtained, the 2¾ in. plunger must be used. At these relatively shallow depths, however, such maximum production per stroke is not frequently required. 2¼ in. or 2¾ in. plungers are most frequently used.

In the lower left corner of this table no values are given because plungers small enough in diameter are not available. To get maximum production per stroke, usually important at these depths, it is necessary to pump at the longer strokes, preferably up to 74 in. Even longer strokes may be found an advantage.

TABLE 8

Increase in Polished Rod Stroke Due to Acceleration—Inches

(3500 Ft., 2½ in. Tubing, 2¼ in. Plunger, ¾ in. Rods, 30 deg. A.P.I. Oil)

Pumping Speed s.p.m.	NOMINAL POLISHED ROD STROKE					
	24 in.	34 in.	44 in.	54 in.	64 in.	74 in.
1	0.00569	0.00805	0.01043	0.0126	0.0152	0.01752
2	0.0227	0.0322	0.0416	0.0511	0.0606	0.0700
3	0.0511	0.0725	0.0936	0.115	0.1360	0.1575
4	0.0903	0.128	0.1655	0.203	0.242	0.278
5	0.142	0.203	0.260	0.320	0.378	0.438
6	0.204	0.290	0.374	0.460	0.545	0.630
7	0.278	0.394	0.510	0.627	0.741	0.857
8	0.364	0.515	0.666	0.820	0.968	1.120
9	0.460	0.651	0.841	1.035	1.225	1.415
10	0.569	0.805	1.043	1.260	1.520	1.752
11	0.686	0.973	1.259	1.545	1.830	2.115
12	0.818	1.16	1.500	1.840	2.18	2.52
13	0.960	1.36	1.760	2.16	2.56	2.96
14	1.113	1.58	2.04	2.51	2.97	3.43
15	1.28	1.81	2.34	2.88	3.41	3.94
16	1.45	2.05	2.66	3.27	3.87	4.47
17	1.635	2.32	3.00	3.69	4.36	5.05
18	1.84	2.61	3.37	4.14	4.90	5.67
19	2.04	2.90	3.75	4.60	5.45	6.30
20	2.27	3.22	4.16	5.12	6.06	7.00
21	2.50	3.55	4.58	5.64	6.66	7.71
22	2.76	3.88	5.03	6.18	7.30	8.45
23	3.00	4.25	5.50	6.75	8.00	9.25
24	3.25	4.63	6.00	7.36	8.72	10.09
25	3.55	5.03	6.51	8.00	9.45	10.93
26	3.82	5.43	7.03	8.63	10.20	11.60
27	4.14	5.86	7.59	9.26	11.03	12.75
28	4.46	6.31	8.17	10.03	11.90	13.73
29	4.75	6.73	8.71	10.70	12.68	14.62
30	5.11	7.25	9.35	11.50	13.62	15.75

ing that a greater portion of the friction will be offset by the gas pressure:

$$\text{Stretch} = \left(\frac{\text{depth of well}}{1000}\right)^2 \times \text{coef. of stretch, or}$$

$$= \left(\frac{3500}{1000}\right)^2 \times 1.755 = 21.4 \text{ inches.}$$

In other words, the movement of the plunger in the pump at slow speeds will be 21.4 in. less than the movement of the sucker rods at the surface of the well.

Since the maximum stroke that is now available with the conventional walking beam equipment is limited to 74 in., maximum plunger diameter is limited as shown in Table 5.

Plunger Diameter and Rod Stretch

For diameters larger than those given in Table 6, practically no stroke is possible (other than that produced by whip at high speeds). For the diameters given, some production is possible, but it is bound to be limited due to the high ratio of rod stretch to rod stroke.

Up to a certain point, production per stroke can be increased by reducing the plunger diameter (and with it the rod stretch), because the gain due to rod stretch is greater than the loss due to plunger diameter reduction. Beyond that point, production will fall off because the gain due to rod stretch reduction will be more than offset by the loss due to plunger diameter reduction.

C. J. Coberly[2] has determined mathematically that the point of maximum production per stroke is obtained with the use of a plunger diameter that will produce a stretch of rods and tubing equal to one-half of the polished rod stroke.

[2]Of Kobe, Inc., Los Angeles, Calif.

Table 7 shows the standard plunger diameter (with ¾-in. rods and 2½-in. tubing) that will give the maximum production per stroke for various combinations of depth of well and length of stroke.

Plunger Diameter for Maximum Production per Stroke

In the East Texas field, where the wells average 3500 ft. in depth, the uncertainties of the allowable volume to be produced may make it necessary to pump at all strokes from 24-in. to 74-in., a 2¼-in. plunger in 2½-in. tubing has been, in many cases, adopted as a fair compromise between the 1½-in. or 1¾-in. that might be best at 24-in. stroke, and the 3¾-in. dia. that might be best at 74-in. stroke.

In cases where the plunger diameter has already been determined, whether because of maximum production desirability, or for other reasons, a stroke length should be selected, if possible, equal to at least twice the rod stretch.

In the East Texas field, for example, for 3500 ft., 2¼-in. plunger, the stretch is 21.4 in., and the minimum stroke should be 21.4 × 2 or 42.8 inches. A 42-in. or 44-in. stroke should give maximum production per stroke. For maintenance reasons, a longer stroke may be found more desirable, even at a sacrifice of production per stroke.

The net plunger stroke at very slow speeds will be equal to the polished rod stroke minus the stretch, or

$S' = S - e$

where:

S' = net plunger stroke in inches

S = polished rod stroke = 2 × crank radius, in inches

e = stretch of rods and tubing, in inches.

TABLE 9

Actual Plunger Stroke for Various Pumping Speeds

(3500 Ft., 2½ in Tubing, 2¼ in Plunger, ¾ in. Rods, 30 deg. A.P.I. Oil, Stretch—21.4 in.)

Pumping Speed s.p.m.	NOMINAL POLISHED ROD STROKE					
	24 in.	34 in.	44 in.	54 in.	64 in.	74 in.
1	2.60	12.61	22.61	32.61	42.62	52.62
2	2.62	12.63	22.64	32.65	42.66	52.67
3	2.65	12.67	22.69	32.71	42.74	52.76
4	2.69	12.73	22.77	32.80	42.84	52.88
5	2.74	12.80	22.86	32.92	42.98	53.04
6	2.80	12.89	22.97	33.06	43.15	53.23
7	2.88	12.99	23.11	33.23	43.34	53.46
8	2.96	13.12	23.27	33.42	43.57	53.72
9	3.06	13.25	23.44	33.64	43.83	54.01
10	3.17	13.41	23.64	33.86	44.12	54.35
11	3.29	13.57	23.86	34.15	44.43	54.72
12	3.42	13.76	24.10	34.44	44.78	55.12
13	3.57	13.96	24.36	34.76	45.16	55.56
14	3.71	14.18	24.64	35.11	45.57	56.03
15	3.88	14.41	24.94	35.48	46.01	56.54
16	4.05	14.65	25.26	35.87	46.47	57.07
17	4.24	14.92	25.60	36.29	46.96	57.65
18	4.44	15.21	25.97	36.74	47.50	58.27
19	4.64	15.50	26.35	37.20	48.05	58.90
20	4.87	15.82	26.76	37.72	48.66	59.60
21	5.10	16.15	27.18	38.24	49.26	60.31
22	5.26	16.48	27.63	38.78	49.90	61.05
23	5.60	16.85	28.10	39.35	50.60	61.85
24	5.85	17.23	28.60	39.96	51.32	62.69
25	6.15	17.63	29.11	40.60	52.05	63.53
26	6.42	18.03	29.63	41.23	52.85	64.20
27	6.74	18.46	30.19	41.86	53.63	65.35
28	7.06	18.91	30.77	42.63	54.50	66.33
29	7.35	19.33	31.31	43.30	55.28	67.22
30	7.71	19.85	31.95	44.10	56.22	68.35

TABLE 11

Production—Barrels of Oil Per 24-Hour Day

(3500 Ft., 2 in Tubing, 1½ in. Plunger, ¾ in. Rods, 30 deg. A.P.I. Oil, 90% Vol. Efficiency.)

Pumping Speed s.p.m.	NOMINAL POLISHED ROD STROKE					
	24 in.	34 in.	44 in.	54 in.	64 in.	74 in.
1	3.23	5.6	7.9	10.3	12.6	15.0
2	6.48	11.2	15.9	20.6	25.3	30.1
3	9.72	16.8	23.9	31.0	38.1	45.2
4	13	23	32	41	51	60
5	16	28	40	52	64	76
6	20	34	48	62	77	91
7	23	40	56	73	90	107
8	26	46	63	84	103	122
9	30	52	72	95	117	138
10	34	58	82	106	130	154
11	38	64	91	117	144	170
12	41	70	99	129	158	187
13	45	77	109	141	171	204
14	49	84	118	153	187	222
15	53	90	127	165	202	239
16	57	96	139	179	220	260
17	61	104	147	190	233	276
18	66	112	157	202	248	294
19	70	119	168	216	265	314
20	75	127	179	230	282	333
21	80	135	190	244	299	353
22	85	143	201	258	316	374
23	90	152	211	273	334	395
24	96	160	224	289	353	416
25	102	169	237	305	372	440
26	107	178	249	321	392	461
27	113	188	263	337	413	486
28	120	198	276	355	434	511
29	126	208	290	372	453	535
30	133	219	305	391	476	562

TABLE 12

Production—Barrels of Oil Per 24-Hour Day

(3500 Ft., 2 in. Tubing, 1¾ in. Plunger, ¾ in. Rods, 30 deg. A.P.I. Oil, 90% Vol. Efficiency.)

P'mp'g Speed s.p.m.	NOMINAL POLISHED ROD STROKE							
	24 in.	32 in.	34 in.	42 in.	44 in.	54 in.	64 in.	74 in.
1	3.21	5.8	6.4	9.0	9.6	12.8	16.0	19.2
2	6.42	11.6	12.9	18	19.3	25.8	32.2	38.6
3	9.65	17.4	19.3	27	29.0	38.7	48.3	58.0
4	13	23	26	36	39	52	65	77
5	16	29	32	45	49	65	81	97
6	20	35	39	55	58	78	97	117
7	23	41	46	64	68	91	114	137
8	27	47	53	74	79	105	131	157
9	30	54	60	83	89	119	148	178
10	34	60	67	93	100	133	166	198
11	38	67	74	103	110	147	179	220
12	42	74	81	113	121	161	197	241
13	46	81	89	124	133	176	220	263
14	50	88	97	135	144	191	238	285
15	54	95	105	146	156	206	257	308
16	59	102	113	157	168	222	277	331
17	64	110	122	169	180	239	297	355
18	69	118	131	181	192	256	318	380
19	74	126	140	192	206	272	338	405
20	79	135	149	207	220	290	360	431
21	84	144	158	218	233	308	382	457
22	90	153	169	232	248	326	405	484
23	95	162	179	246	263	346	429	513
24	101	172	190	260	278	365	453	541
25	109	182	201	275	293	385	478	569
26	116	193	212	290	309	406	503	598
27	123	204	224	306	326	427	530	631
28	130	216	236	322	343	451	557	663
29	137	227	249	339	361	472	584	695
30	146	239	265	356	379	496	614	730

TABLE 13

Production—Barrels of Oil Per 24-Hour Day

(3500 Ft., 2½ in. Tubing, 1²⁵⁄₃₂ in. Plunger, ¾ in. Rods, 30 deg. A.P.I. Oil, 90% Vol. Efficiency.)

Pumping Speed s.p.m.	NOMINAL POLISHED ROD STROKE					
	24 in.	34 in.	44 in.	54 in.	64 in.	74 in.
1	3.50	6.80	10.1	13.5	16.8	20.2
2	7.01	13.6	20.3	27.0	33.6	40.4
3	10.52	20.5	30.5	40.5	50.6	60.6
4	14	27	41	54	68	81
5	18	34	51	68	84	101
6	21	42	62	82	101	122
7	25	49	72	96	118	143
8	29	56	83	110	137	164
9	33	63	94	125	155	185
10	37	71	105	138	172	206
11	41	79	116	154	191	230
12	45	86	128	169	211	252
13	50	95	140	185	230	275
14	54	103	151	201	249	298
15	59	111	164	216	269	322
16	64	120	177	233	290	346
17	69	129	190	250	311	371
18	74	138	204	268	332	397
19	79	148	216	286	354	423
20	84	158	231	304	378	450
21	91	169	246	323	400	477
22	97	178	260	342	423	505
23	103	190	276	362	448	535
24	110	201	292	382	473	564
25	117	212	308	403	499	594
26	123	224	324	426	526	624
27	132	235	342	446	554	658
28	139	250	361	472	582	692
29	147	263	379	494	610	726
30	156	278	398	520	641	762

At higher speeds the inertia of the reciprocating parts forces the plunger to overtravel; and the plunger stroke is increased by the amount of overtravel.

C. J. Coberly,[3] in his comments on Marsh's paper,[1] gives a formula for computing this overtravel. The formula is based on the acceleration of the rods due to their own weight. The acceleration of the oil is neglected, which will affect the result by a few per cent.

$$e - e' = 0.00193\ (LN)^2$$

where $e - e'$ = overtravel of plunger in per cent of polished rod travel

L = length of sucker rod in thousand feet

N = strokes per minute.

In the East Texas field, for example, this overtravel of plunger will be as given in Table 8.

It will be noted that the increase of plunger stroke, due to acceleration for speeds less than 10 s.p.m., is not large and may frequently be neglected.

[3] A.P.I. Production Bulletin No. 207.

TABLE 10

Displacement in Bbl. Per Day, at 1 s.p.m. for Each Inch of Plunger Travel

Plunger Diameter	Production Constant	Plunger Diameter	Production Constant
1 in.	0.117	$1^{15}/_{16}$ in.	0.438
$1^{1}/_{16}$ in.	0.132	$2^{1}/_{4}$ in.	0.590
$1^{1}/_{2}$ in.	0.262	$2^{7}/_{16}$ in.	0.692
$1^{3}/_{4}$ in.	0.357	$2^{3}/_{4}$ in.	0.882
$1^{25}/_{32}$ in.	0.370	$3^{3}/_{4}$ in.	1.640

TABLE 14

Production—Barrels of Oil Per 24-Hour Day

(3500 Ft., $2^{1}/_{2}$ in. Tubing, $1^{15}/_{16}$ in. Plunger, $^{3}/_{4}$ in. Rods, 30 deg. A.P.I. Oil, 90% Vol. Efficiency.)

Pumping Speed s.p.m.	NOMINAL POLISHED ROD STROKE					
	24 in.	34 in.	44 in.	54 in.	64 in.	74 in.
1	2.72	6.1	9.5	12.9	16.5	19.7
2	5.45	12.2	19.2	25.9	32.7	39.5
3	8.21	18.4	28.6	38.8	49.1	59.3
4	11	25	38	52	66	79
5	14	31	48	65	82	99
6	17	37	58	79	99	119
7	20	44	68	92	116	140
8	23	50	78	105	133	161
9	26	57	88	119	151	181
10	29	64	98	133	168	203
11	32	71	109	148	186	225
12	36	78	120	162	204	245
13	40	86	131	177	224	269
14	43	93	143	193	242	292
15	47	101	155	208	262	315
16	51	109	167	224	282	340
17	56	117	179	241	302	364
18	60	126	192	258	324	390
19	65	135	205	275	345	415
20	70	144	218	293	368	441
21	75	154	232	311	390	468
22	80	164	247	330	413	496
23	86	174	262	350	437	526
24	92	185	278	370	462	555
25	97	196	293	391	488	585
26	104	207	310	412	515	625
27	111	219	326	435	542	649
28	118	231	344	458	569	682
29	126	244	362	480	598	716
30	134	258	381	505	628	752

TABLE 15

Production—Barrels of Oil Per 24-Hour Day

(3500 Ft., $2^{1}/_{2}$ in. Tubing, $2^{1}/_{4}$ in. Plunger, $^{3}/_{4}$ in. Rods, 30 deg. A.P.I. Oil, 90% Vol. Efficiency.)

Pumping Speed s.p.m.	NOMINAL POLISHED ROD STROKE					
	24 in.	34 in.	44 in.	54 in.	64 in.	74 in.
1	1.38	6.71	12.0	17.3	22.6	28.0
2	2.78	13.4	24.1	34.7	45.3	56.1
3	4.22	20.2	36.2	52.1	68.1	84.0
4	6	27	48	70	91	113
5	7	34	61	87	114	141
6	9	41	73	105	137	170
7	11	48	86	123	161	198
8	13	56	98	142	185	228
9	15	63	112	161	209	259
10	17	71	125	180	234	288
11	19	79	140	200	260	320
12	22	87	154	220	285	352
13	25	95	168	240	313	384
14	28	105	183	261	338	417
15	31	115	199	283	367	452
16	34	124	213	305	395	485
17	38	135	231	328	425	522
18	42	145	248	351	455	556
19	47	156	266	375	486	595
20	52	168	284	400	516	634
21	57	180	303	427	550	670
22	62	193	324	453	583	715
23	68	206	343	481	618	755
24	75	220	364	509	655	795
25	82	235	386	540	693	845
26	89	249	410	570	729	888
27	97	265	443	600	770	935
28	105	282	457	635	811	985
29	113	298	482	667	850	1035
30	123	317	510	705	896	1090

TABLE 16

Production—Barrels of Oil Per 24-Hour Day

(3500 Ft., 3 in. Tubing, $2^{3}/_{4}$ in. Plunger, $^{3}/_{4}$ in. Rods, 30 deg. A.P.I. Oil, 90% Vol. Efficiency.)

Pumping Speed s.p.m.	NOMINAL POLISHED ROD STROKE					
	24 in.	34 in.	44 in.	54 in.	64 in.	74 in.
1	0.0	3.02	11.0	18.9	26.9	34.8
2		6.06	22.0	37.8	53.8	69.6
3		9.21	33.0	56.9	80.8	104
4		12	44	76	108	140
5		16	56	96	135	175
6		19	67	115	163	210
7		23	79	135	196	248
8		27	87	156	220	285
9		32	104	177	251	323
10		37	118	197	280	362
11		42	131	221	311	400
12		47	145	245	343	440
13		53	160	268	374	482
14		60	176	292	407	524
15		67	192	317	443	562
16		74	209	344	478	611
17		82	226	371	513	658
18		91	245	398	553	706
19		101	264	428	592	756
20		111	285	459	634	806
21		122	306	491	674	860
22		134	328	523	717	911
23		147	353	556	763	970
24		161	377	603	811	1025
25		175	402	631	859	1085
26		190	430	670	910	1140
27		206	457	706	959	1210
28		224	487	751	1010	1280
29		242	518	794	1070	1340
30		262	550	840	1130	1420

TABLE 17

Production of 70 Bbl. of Oil Per Day at Various Pumping Speeds, East Texas Field

Speed	Stroke	Speed	Stroke
23.3 s.p.m.	24 in.	4.0 s.p.m.	54 in.
9.8	34 in.	3.1	64 in.
5.7	44 in.	2.5	74 in.

The net plunger stroke at high speeds will be:

$$S' = S - e + \frac{0.00193}{100} (LN)^2 S$$

$$= S [1 + 0.0000193 (LN)^2] - e$$

Taking East Texas field as an example, 3500-ft. depth, $2^{1}/_{2}$-in. tubing, $2^{1}/_{4}$-in. plunger, $^{3}/_{4}$-in. rods, 30-deg. A.P.I. oil, the net plunger stroke will be as given in Table 9.

If the pumping speed is so high that the acceleration of the polished rod due to the crank motion is greater than the acceleration due to gravity, the plunger stroke will increase and cause buckling of the sucker rods. Theoretically, this condition exists at 54 s.p.m. on 24-in. stroke, 46 s.p.m. on 34-in. stroke, 40 s.p.m. on 44-in. stroke, 36 s.p.m. on 54-in. stroke, 33 s.p.m. on 64-in. stroke, and 31 s.p.m. on 74-in. stroke.

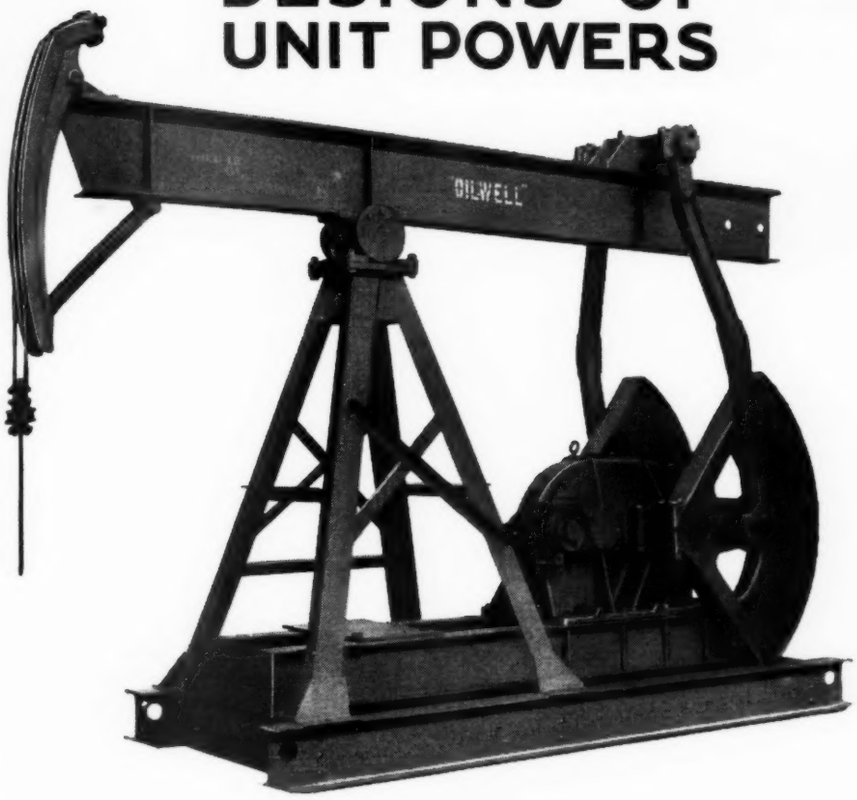
The total production in barrels per day is equal to the effective plunger stroke (in inches) $\times$ s.p.m. $\times$ volumetric efficiency $\times$ pump constant.

The constants in Table 10 may readily be computed from the ordinary rules of mensuration.

In the case of the East Texas field, where the plunger diameter is assumed to be $2^{1}/_{4}$-in., the constant is 0.59, and assuming a volumetric efficiency of 90 per cent, the total daily production will be as given in Table 15. The total daily production for the size of plunger and tubing are given in Tables 11 to 16, inclusive.

"OILWELL'S" NEW

DESIGNS OF UNIT POWERS



TC-20 TWIN CRANK UNIT PUMPING POWER

Capacity: **14,000-lbs. dead weight polished rod load; Horsepower input—20 H.P. electric motor, or 35 H. P. gas or oil engine.**

Flexibility: **up to 26 strokes per minute; stroke lengths 22½", 30", 37½", 45", 52½".**

Convenience: **many time-saving operating features.**

ESTABLISHING TOTALLY NEW STANDARDS FOR TROUBLE-FREE OPERATION, THE NEW TC-20 PRODUCTION UNIT introduces many special features. Pivoted Equalizer and self-aligning upper and lower pitman Bearings provide *positive equalizing of the load* on the two pitmans and cranks. Twin counterbalanced cranks assure smooth operation. Arc welded structural steel Base and Samson Post are unusually strong and rigid. *Ask for details at nearest Branch Store.*

ODH-18 UNIT PUMPING POWER

The ODH-18 unit pumping power is typical of "OILWELL'S" new line of single crank production units. The capacity rating is slightly under that of the TC-20, but the rigid arc welded construction and design are the same except as illustrated.

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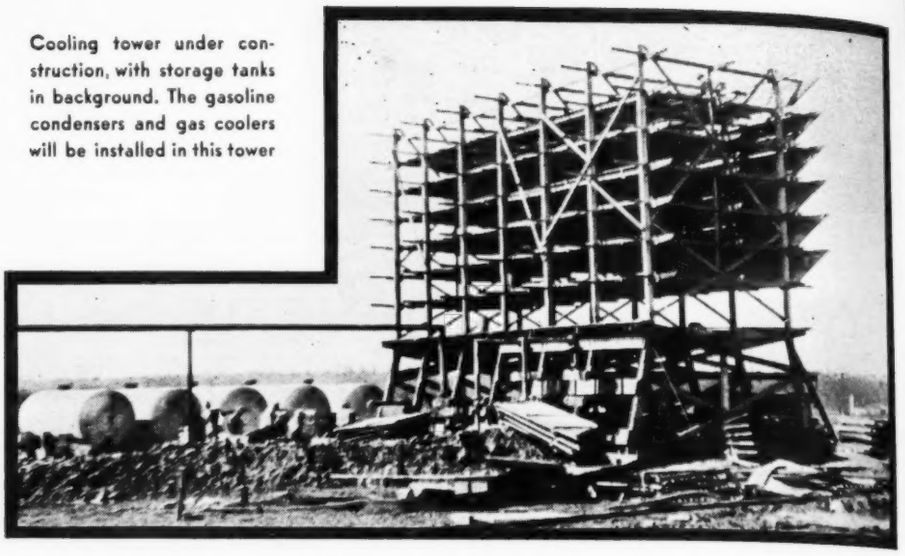


Cooling tower under construction, with storage tanks in background. The gasoline condensers and gas coolers will be installed in this tower

New Holdenville Natural Gasoline Plant Equipped to Handle High Pressure Gas

Crosbie-Moran, Inc., plant, first in rich gas yielding pool, is practically automatic in operation

Crosbie-Moran, Inc., of Tulsa, Okla., has recently completed the first natural gasoline plant in the West Holdenville, Okla., pool. This plant is representative of the modern type natural gasoline manufacturing unit, being very compact and, through the use of control instruments and regulating devices, its operation will be almost entirely automatic. Due to the fact that varying well pressures exist in the field, the plant has been designed to handle, without use of compressors, both high-pressure and low-pressure gas. The high-pressure absorber and the low-pressure absorber will operate at 400 lb. and 75 lb., respectively.

Although the plant has a capacity of 60 million cu. ft. of gas per day, only half of this quantity will be processed at the present time. The company has a market for 25 million cu. ft. of residue gas daily but it is anticipated that this amount will later be increased. The location of the plant makes it easily accessible to a huge quantity of available gas, the West Holdenville pool being a prolific gas producing area. The nearness of gas production to the plant is best indicated by the fact that the main gathering system is only a quarter of a mile in length.

Tulsa-type equipment has been installed in the plant, some of which was shipped from other plants operated by Crosbie-Moran in the state. The Continental Supply Co. furnished fittings and other equipment through Wewoka, Okla., store.

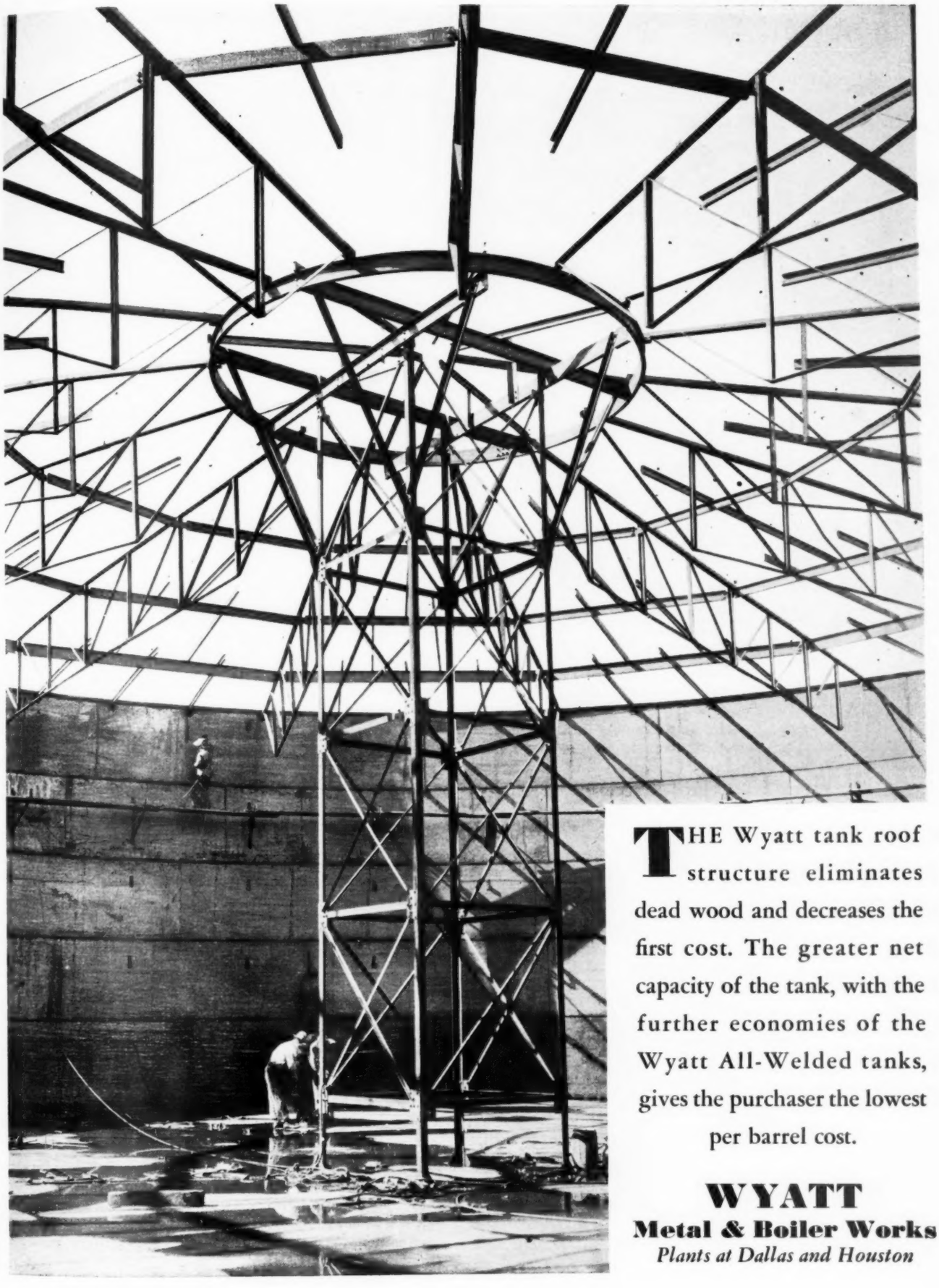
The rich oil will be distilled in a Tulsa unit that consists of two insulated bubble towers and heat exchangers. The gasoline condensers and gas coolers are installed in a Pritchard cooling tower. Two Griscom-Russell sections will be used as condensers and six sections for cooling the hot oil after it leaves the heat exchangers at the still.

Both steam- and motor-driven centrifugal pumps will be used to handle the oil and water in the plant, the steam pumps being installed as stand-bys. Three 75-hp. field boilers will generate the steam for the pumps and distillation unit, while a generator driven by a 100-hp. Clark gas engine will furnish sufficient electricity for light and power requirements. So that all the steam energy possible may be conserved, the company has installed an atmospheric condenser on the exhaust steam line by means of which the exhaust condensate will be recharged into the boilers as feed water.

A new stabilizing unit will be erected to produce natural gasoline of various vapor pressures. The bubble tower is 40 in. in diameter and 30 ft. high. Welded joints have been used in fabricating the piping and on the field gathering lines, while all the units are set in concrete foundations.

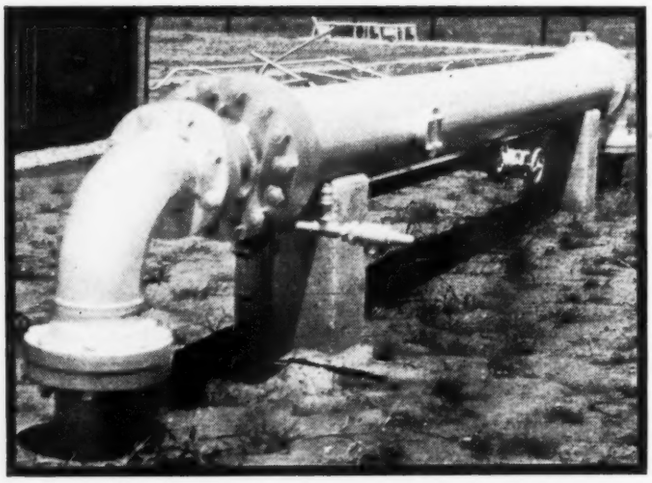
The control and regulating devices will consist of 4-in. Buffalo meters for measuring the oil to the absorbers; Fisher liquid level controls on the absorbers and still towers; and Neilan pressure regulators for controlling the gas pressures. Neilan temperature controls and recorders have been placed on the distillation and stabilizing units, while Westcott orifice meters are to be used to measure the gas. The finished gasoline will be stored in a battery of five horizontal tanks, each 7 ft. by 28 feet. The gasoline manufactured is sweet and requires no chemical treatment.

A sheet metal building houses the office, store room and testing laboratory. This plant, the sixth one for the Crosbie-Moran interests in the state, was constructed under the supervision of Steve Neeley, general superintendent for the company. D. B. Young will be in charge of its operations.



THE Wyatt tank roof structure eliminates dead wood and decreases the first cost. The greater net capacity of the tank, with the further economies of the Wyatt All-Welded tanks, gives the purchaser the lowest per barrel cost.

WYATT
Metal & Boiler Works
Plants at Dallas and Houston



A high-pressure jacket water cooler on discharge line from pump

By J. M. TOTTEN
The Griscom-Russell Co.

Pipe Line Station

Water Cooling Systems

Utilizing Crude Oil

Tendency is toward the installation of closed type coolers on discharge side of stations to prevent vaporization

MANY jacket water cooling systems constructed for oil pipe line service in the past 18 months have been of the closed type in which crude oil is used to cool the jacket water. Such a system consists of a shell and tube exchanger located in the oil line on the suction or discharge side of the main line pump, a water circulating pump, suitable piping to and from the engine jackets, and a surge tank.

In most cases oil is passed through the tubes of the exchanger, the jacket water being pumped through the shell, thence to the prime mover jacket and from there to the surge tank. Fig. 1 shows a representative layout. Tubes of ¾-in. outside diameter appear to be the most desirable size for this type of exchanger. A smaller tube would be too likely to clog, whereas tubes of larger diameter would result in a longer, bulkier cooler for the same capacity.

Some installations have been made in which a separate cooler has been supplied for each engine. This method may be justified where different types of engines are used in the same station that require different jacket water temperature ranges. Where all engines are identical, the correct installation consists of all the coolers manifolded in the discharge line with a spare unit representing 20 per cent to 30 per cent of the total capacity. Many jacket water coolers have been installed in pits below the ground level. The reason for this apparently being the simplification of the oil piping. The greater ease of inspection and increased accessibility obtained with coolers installed above ground justify the slight additional piping expense involved. It is possible to drain the coolers more easily when installed above ground.

Flexible couplings on the oil and water connections also possess several advantages. The cooler can be quickly installed and removed from the line. This type of connection prevents, to a great extent, the transmission of vibration from the piping to the cooler. A slight misalignment does not result in a leaky joint with this method of connecting.

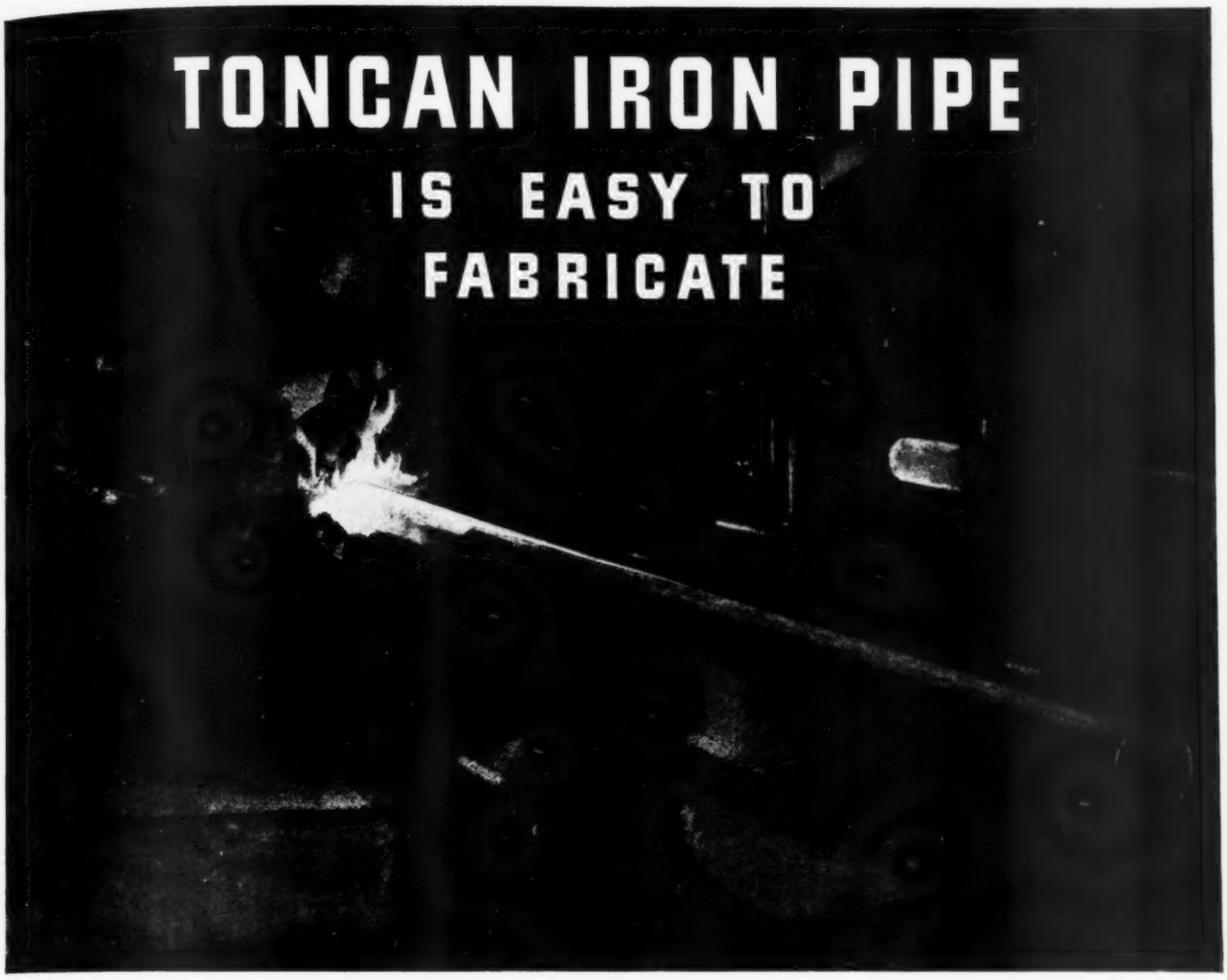
With respect to the water system, it is highly important that the suction line from the surge tank to the circulating pump be of ample size and as short as possible. The piping carrying the hot jacket water from the engine to the surge tank should have sufficient upward slope from engine to tank to allow any air to be vented that might tend to air-bind the engine jacket. Fig. 1 shows a practical way to connect water piping so that positive circulation will always be obtained. This diagram shows a centrifugal oil pump driven through a step-up gear by an oil engine. A small centrifugal water circulating pump is driven off an extension of the main pump shaft. This assures the operation of the pump whenever the engine operates.

Air, which may be entrained with the jacket water, is vented at the top of the surge tank. This tank also takes care of the expansion of the water in the system as the temperature rises after the engine is started, and should be provided with a gauge glass and drain connections; also inlet connections from make-up water supply.

Drain connections must be provided on both the shell and tube sides so that in cold weather jacket water and oil may be drained out of the shell or any idle cooler. Because of the various duties of station attendants that require them to leave the engine room, the engines at times operate unattended. For this reason it is an inexpensive form of insurance to equip the engines with thermostatic alarm systems to indicate, by ringing a gong, any overheating of jacket water.

Most of the earlier installations of coolers were made on the suction side of the main pumps, but the tendency at present is to locate them in the discharge line. The main reason for placing the cooler in the suction line was to avoid heavy construction necessitated by high working pressure. But since heavy construction is frequently used to withstand corrosion it appears that the cooler need not be placed on the suction side because of this factor. On the discharge line there is no possible chance for vaporization in the cooler even with the lightest crudes.

TONCAN IRON PIPE
IS EASY TO FABRICATE



Every fabricator who has ever used Toncan Iron Pipe knows how easy it is to work. Because of its ductility, it works very readily, either cold or hot. Because it contains almost no carbon, heat treating does not result in hardening. It can be normalized to relieve strains and to improve grain structure after working. And it is easily threaded or welded.

For these reasons you can safely specify Toncan Iron Pipe for any installation requiring flaring, bending, belling, welding, threading or vanstoning. Your fabricator will bear out this statement and, furthermore, if any doubts exist in your mind, will be glad to take you right out into his plant where you can see these operations performed by ordinary shop-practice methods.

Toncan Iron Pipe is now universally recognized as the modern alloy of refined iron, copper and molybdenum, with rust-resisting qualities placing it first among the ferrous metals after stainless steel. This rust-resistance can be made uniform throughout any piping installation by the use of Toncan Iron couplings and threaded fittings, welding fittings and welding rod—all of the same analysis as the pipe itself.

Write for additional information on these vital subjects of fabrication and resistance to rust.

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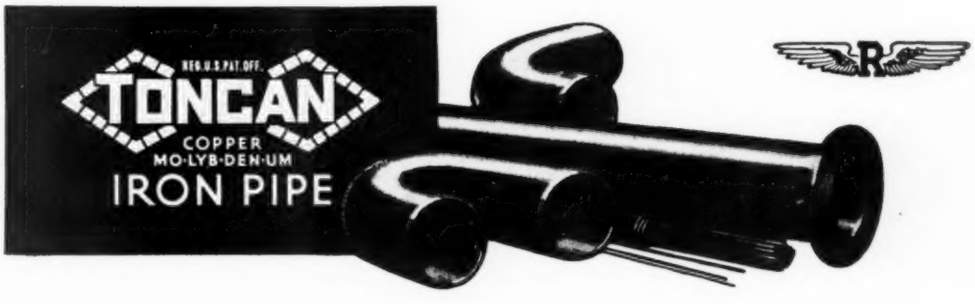


By keeping the cooler out of the suction line the pumps can be relied upon to fill properly. In addition, too, a higher pressure drop on the oil side of the cooler can be allowed, which results in a smaller cooler for a given capacity. Some oils have a tendency to deposit paraffin when the velocity and temperature are low, such as East Texas crude, and in these cases there would be far less likelihood of paraffin depositing in the coolers located in the discharge line than in coolers in the suction line.

The following incident is in itself a very good argument for locating the cooler in the discharge line. On a certain oil line there were two stations in series, the first station consisting of engine-driven reciprocating pumps discharging into the line at 800 lb. per sq. in. Friction losses, etc., resulted in a line pressure of 250 lb. per sq. in. at the inlet to the crude oil jacket water cooler of the booster station farther down the line. For some reason, such as a slug of water or dirt, the fuel supply to the booster station engines was interrupted, the pumps stopped and before the attendant could by-pass the oil around the jacket water cooler, the pressure had built up to 800 lb. per sq. in. in the cooler. The valves failed to function and, in consequence, one of the tube connections failed, causing a considerable loss of oil and the expense of a shutdown.

By far the greatest liability from fouling is on the crude oil side of the cooler. Any accumulation in the tubes will soon be evident from an increased oil pressure drop through the cooler and decreased heat transfer. The heads can be removed and the tubes cleaned with a scraper and an air lance. In some cases, a thorough flushing with a cleaning compound will be all that is necessary. Because it is a difficult job to clean the shell side of a collar with non-removable tube bundle, it is very important that the initial charge of jacket water be free from scale-forming solids. As to the make-up water, any reasonably good water will do as the quantity of make-up is very small. Hand-hole plates should be furnished on the shell to permit inspection of the tube bundle at those points that cannot be seen through the shell nozzles.

A single-pass cooler on both the shell side and the tube side is to be preferred because of lower first cost and lower pressure drop. However, space limitations sometimes demand that a short two-pass cooler be used instead of the larger single-pass cooler. If necessity demands a cooler having two-pass tubes, it is best to construct the shell for two passes also in order that true counter-flow temperature difference may be obtained.

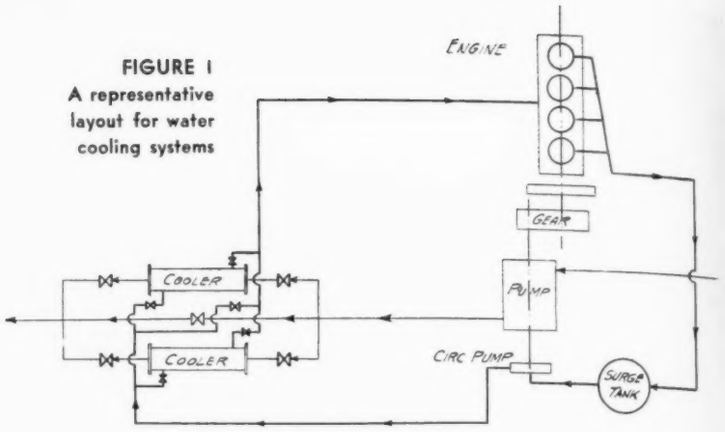


FIGURE 1
A representative layout for water cooling systems

In order to design intelligently a jacket water cooler, the following data must be known: quantity of jacket water, temperature range of jacket water, allowable pressure drop of jacket water through cooler, maximum possible temperature of crude oil at inlet of collar, gravity and viscosity of crude oil, allowable pressure drop of oil through the cooler, space limitations, size of oil piping and of water piping, and location of cooler with respect to pump.

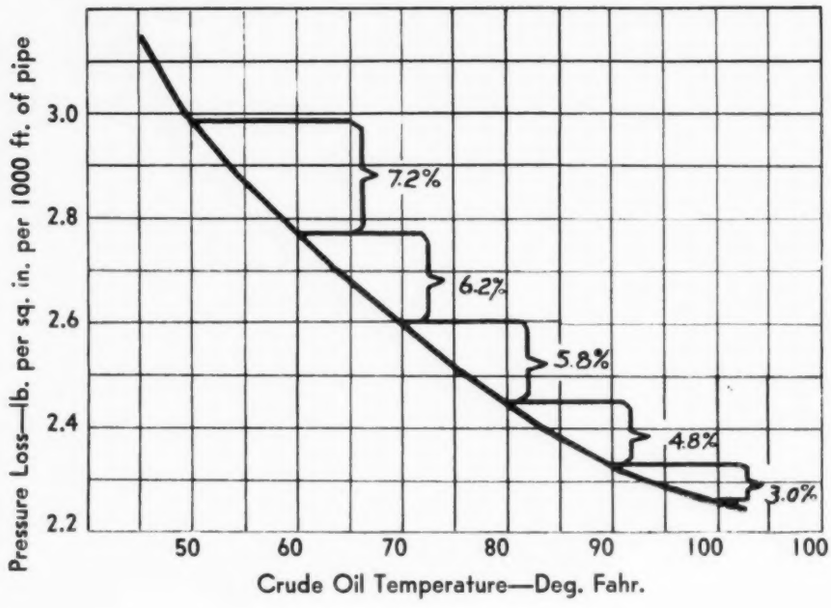
At first glance, it would appear that the quantity of crude oil should be known. In nearly every case the station will handle much more oil than is actually needed to cool the jacket water. This will mean that some of the crude oil will be by-passed around the coolers.

Curve 1 shows the relation between the crude oil temperature and theoretical pressure loss due to friction per 1000 ft. of 10-in. I.D. pipe carrying 30,000 bbl. per day of 39 deg. A.P.I. crude oil. A study of this curve reveals the fact that for a given oil temperature change the effect upon friction loss is greatest at the low temperature.

Curve 1 also shows the percentage reduction in friction loss for each 10 deg. increase in oil temperature from 60 deg. to 110 deg. fahr. It will be noted that by heating the oil from 60 deg. to 70 deg., a 7.2 per cent reduction is effected, while heating the oil from 100 deg. to 110 deg. fahr. results in only a 3.0 per cent reduction in friction loss.

During the winter months not all the crude oil is needed to cool the jacket water, some is therefore by-passed around the cooler. The resulting temperature of the mixed warm and cold oil is very likely only two degrees or so above the initial oil temperature.

In the warmer months, more, if not all, of the oil is passed through the cooler, but now its initial temperature is much higher, at say 90 deg. fahr. The reduction in the theoretical friction loss will not be more than four or five per cent. In actual practice, this reduction will no doubt be even less than four per cent. However, regardless of the amount of power saved, the heat in the jacket water is at least being utilized in the right direction and is not being dissipated into the atmosphere.



Curve 1, showing relation between the crude oil temperature and theoretical pressure loss due to friction per 1000 ft. of 10-in. I.D. pipe carrying 30,000 bbl. per day of 39 deg. gravity A.P.I. crude

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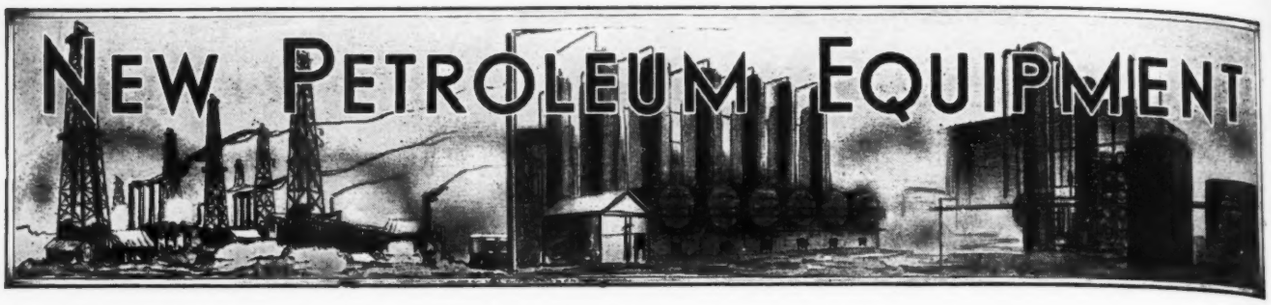
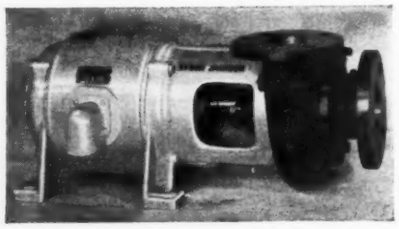


Byron Jackson Develops Bilt-On Pump

INTERESTING both from the standpoint of design and efficiency is the new direct-connected, centrifugal pump recently developed by Byron



Jackson Co., Berkeley, Calif., which is known as the "Bilt-On."

The illustration is of the 2½-in. Bilt-on pump, direct-connected to a 3-hp. 2900- or 3500-r.p.m., 2-pole, 220- or 440-volt motor. The pump has a 3-in. suction nozzle and a 2½-in. discharge nozzle that can be vertically up, horizontally over, vertically down or horizontally under.

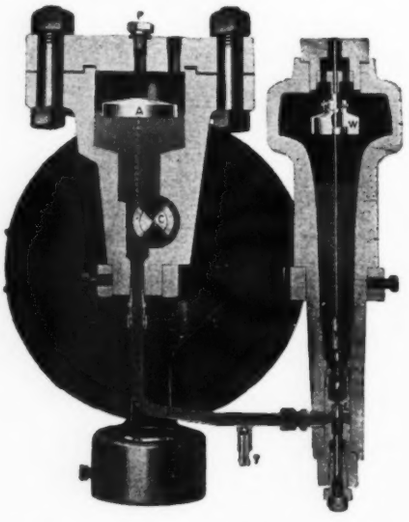
This size, with capacity of 200 g.p.m. against a 55-ft. head, is designed for bulk loading, handling gasoline, oil, kerosene, or as a water pump. A complete line in various sizes is contemplated, with important reductions in both price and weight by the elimination of the customary base and the flexible coupling. The casing and suction cover is of cast iron, and of heavy construction. The runner of bronze is of the flat-back type, which creates a slight pressure on the stuffing box and prevents air from entering the pump casing. The shaft has a renewable sleeve where it passes through the stuffing box. The gland is of split design, with reflector between the gland and the motor bearing, to prevent any liquid that might leak out of the stuffing box from getting into the bearing.

Additional data, specifications and prices may be obtained from the manufacturer.

Magnetic Clutch Flow Controller

THE C. J. Tagliabue Mfg. Co., of Brooklyn, N. Y., is offering to the trade the Tag Magnetic Clutch Flow Controller in which the conventional pressure-tight bearing has been discarded in favor of a perfected magnetic clutch. The manufacturer claims this has done away with friction, leakage and maintenance at that point. This departure from the usual practice has also enabled the company to manufacture a unit of regular construction suitable for 2500-lb. working pressure, and to locate all internal parts so that they are immersed in the mercury and protected by it against moisture, dirt and corrosion.

When the float moves the rotor turns instantly. When the rotor turns, the



Cobalt steel magnets turn exactly the same amount because the rotor and magnets are locked together by the invisible but powerful magnetic field. The rotor turns in a closed-end cylinder of non-magnetic stainless steel. The magnets outside this cylinder are mounted on ball bearings and transmit the movement to the pen. They are completely shielded and are housed in a dust proof case.

The low-pressure leg can be interchanged by the user so that the differential range can be made either 20-in., 50-in., 100-in., or 250-in. A 100-in. range volumeter is also available that enables the operator to use a chart graduated uniformly in units of flow that is particularly desirable for rate-of-flow control work instead of the "progressive" chart.

Other features are: improved orifice holding ring with meter connections allowing use of standard flanges; universal mounting for 2-in. vertical pipe or wall (surface) or panel (flush) needle dampening valve adjustable during operation; improved stainless steel check valve, positively preventing blowing out mercury; balancing control feature on controllers preventing "hunting"; and pilot valve instantly reversible from direct to reverse acting.

Pacific Pump Works Adds to Pump Line

THE Pacific Pump Works of Huntington Park, California, builder of centrifugal pumps for oil refineries, has added a new line of deep-well oil pumps to its list of products.

In addition, the company has established a subsidiary shop and organization at Tulsa, Okla., known as the Mid-Continent Pump Supply Company. This company carries a full supply of liner pumps and renewal parts, and is well equipped for service, including the regrinding of plungers and liners. The Mid-Continent Pump Supply Company is headed by Roy A. Dunbar, who has been prominent in the oil well pump industry for many years.

In announcing the oil well pump line, George A. Bigelow, general manager of the Pacific Pump Works, stated:

"After careful investigation, we are convinced that the insert liner pump, wherever it can be used, is a most efficient and reliable pump for pumping of oil from deep wells. When backed up by an efficient regrinding service, such as we have established at Tulsa and Huntington Park, oil production costs are materially reduced."

All Stainless Tape-Rule

As a companion to its "Crescent" Tape-Rule, No. 696, The Lufkin Rule Co., Saginaw, Michigan, has just brought out "All Stainless Crescent" No. S-696.

In this new flexible-rigid 6-ft. tape-rule, genuine stainless steel is used not

only for the graduated blade and its sliding hook, but also for the case. This makes the article rust-proof and non-corrosive, a most valuable and practical improvement, as tape-rules, like rules and tapes, often become damp and are used where rusting is hard to prevent. Under such conditions the "All Stainless" will, without any special care, keep itself in good shape.

It is offered marked inches to 16ths, for general use; and for engineers' use there is No. S-696-D, the upper edge of which is graduated in feet, 10ths and 100ths of feet, and the lower edge in feet, inches and 16ths.

Tape-rules are coming into very widespread use because they combine the accuracy and convenience of a pocket steel tape with the utility of both a rule and a tape.

International One-Half Ton Truck

The addition of the new one-half-ton, six-cylinder Model D-1 to the International truck line makes it possible for users of light delivery units to avail themselves of this make truck.

It is a quality truck built to International standards and sold at the lowest price ever quoted on an International chassis. This sturdy 113-in. wheelbase chassis is powered by a six-cylinder engine of modern high-compression design that develops 66 hp. Downdraft carburetion, and full-pressure lubrication to main, connecting rod and camshaft bearings are important engine features. The 9-in. clutch is of the single-plate type with built-in vibration damper. The transmission has three speeds forward and one reverse.

The final drive is of the spiral-bevel gear type with semi-floating axle shafts. Semi-elliptic front and rear springs are of chrome-vanadium steel and have self-adjusting shackles. Five 40-spoke, 18-in. wire wheels and a left front fender well, spare wheel and tire carrier are standard equipment.

Complete details will be supplied by the nearest International Harvester Company branch or International truck dealer or communicate direct with the company at Chicago, Ill.

Oil Well A.P.I. Imperial Plunger Pumps

The Oil Well Supply Company, Dallas, Texas, has announced a new line of plunger pumps built in strict accordance with A.P.I. specifications and featuring extremely accurate bore with mirror-like honed and polished finish. The new plunger pumps, designated Oil Well Imperial A.P.I. Type 32, are regularly furnished in two designs—nickel-alloy cast-iron barrel design and machined liner design.

The nickel-alloy cast-iron barrels are furnished with either regular or reinforced ends. The reinforced ends are of larger outside diameter than regular ends, with the reinforced sections extending beyond the threads for a short distance, and are recommended for severe service and where pumping depths exceed 4000 feet. The barrels are cast in one solid piece and annealed to relieve all strains and prevent subsequent warping. The solid casting is bored on a special machine that assures a straight bore from end to end. The bore is reamed and finally ground and honed on a specially constructed machine that insures a true and highly-polished gun-barrel finish. Couplings for plunger pumps with nickel-alloy cast-iron barrels are made of high-grade malleable iron with standard tubing threads at the tubing ends. The lower coupling has a carefully machined seat for tapered cut nut of the standing valve.

The barrel of the plunger pump with machined liner consists of a cast and annealed nickel-alloy-iron liner encased in a jacket made of special cold-drawn tubing. Especially long interlocking liner sections are an exclusive feature insuring a liner of straight and uniform bore and reducing the number of joints to a minimum. These pumps are designed to provide the advantage of easy replacement of liners in the field without the use of special tools or mandrels. Each liner is bored from a solid annealed casting and is given a true and mirror-like finish in the same manner as the barrel of the nickel-alloy cast-iron barrel plunger pump. Both ends of the liner are cut off square with the axis of the bore and inside corners are chamfered to facilitate lowering the plunger into the liner. The couplings for the plunger pump with machined liner are machined from cold-rolled steel bar stock and are made in strict accordance with A.P.I. specifications.

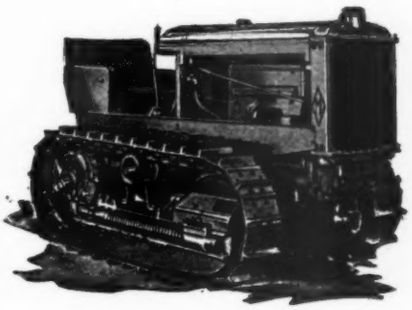
Plungers for both designs of Imperial A.P.I. Type 32 plunger pumps are made from special cold-drawn tubing and are corrugated, providing a liquid seal that effectively prevents fluid slippage. The plungers are accurately ground and polished to diameters in accordance with A.P.I. fits.

Upper and lower valve cakes are machined for close clearance and short lift, increasing the efficiency and life of the pump. The top of each guide is square so that either a ball or drop can be used in the same cage. The pumps are regularly equipped with 2-cup all-steel standing valves with Oberly type cut nuts, but, if desired, the new oversize standing valve, which reduces fluid restriction, can be used.

Allis-Chalmers Track-Type Tractor

The latest addition to the Allis-Chalmers Manufacturing Company, Milwaukee, Wis., line of track-type tractors is Model "M." This model follows the general design of the A-C Model "35" and Model "L."

It is equipped with four speeds forward, renewable cylinder sleeves, unit construction, steering clutch control and many other features. Ample power



is furnished by an engine that will deliver approximately 28 drawbar horsepower. The weight of the unit is 6200 lb. and is equipped with 12-in. width track shoes. The list price is $1650 F. O. B. Springfield, Ill.

The wide variation of speeds, 2.23 to 5.82 miles per hour, greatly increases this tractor's range of usefulness. The ability of this machine to work at high speed in loose or wet soil and its ease of handling in close quarters make it especially adaptable to the oil industry.

W. S. ACKERMAN, assistant to the manager of transportation for the Associated Oil Company, has been appointed a member of the 1933 sub-committee of statisticians and economists of the American Petroleum Institute. Mr. Ackerman has been in the service of Associated continuously since 1906. In addition to his duties as assistant to the manager of transportation, he has charge of statistical information concerning production, purchases and stocks of crude oil products.

O. R. ELMORE, chief gauger for the Stanolind Oil & Gas Co., is now residing at Oil City, La. He recently moved there from Tree City, La.

W. T. DANNER of the Carter Oil Company is now division clerk at Seminole, Okla., having been transferred from his previous residence at Oilton, Okla.

N. V. VANNIKOFF, representative of Amtorg Trading Corporation, will henceforth be located at 354 South Spring Street, Los Angeles, Calif. Mr. Vannikoff was formerly located at 261 Fifth Street, New York City.

F. J. KING, chief engineer of the Linde Air Products Company, was elected president of the Compressed Gas Manufacturers' Association at the annual meeting held at the Waldorf-Astoria, New York City. Mr. King has made many contributions to the technical progress of the compressed gas industry and has been closely identified with the manufacture of oxygen and acetylene and the development of their applications since joining the Linde Air Products Company in 1909.

TOM JACKSON, South Texas and Gulf Coast representative for the Petroleum Equipment Company and Oil Field Engineering Corporation of Fort Worth, Texas, has moved his Houston, Texas, warehouse and offices to 3205 Harrisburg Boulevard.

LAPRADE STEWART, formerly of Casper, Wyo., is now resident engineer at Cut Bank, Mont., for the Santa Rita Oil and Gas Company. He was formerly identified with the pipe line industry.

A. P. KUSH, formerly with the Magnolia Petroleum Company at Fort Worth, Texas, is now associated with the White Eagle Oil and Refining Company as refinery chemist at the company's Augusta, Kan., plant.

JAMES HUTCHESON, vice-president and general manager of the Rio Bravo Oil Company, Houston, Texas, was a New York City business visitor last month.

P. M. NEWHALL, general manager of the North Venezuela Petroleum Company, has returned to Venezuela via New York City and London, after spending several months at Berkeley, Calif.

G. L. KOTHNY, vice-president and general manager of the Sperry-Sun Well Surveying Company, Philadelphia, Pa., was a recent business visitor to his company's office at Dallas, Texas.

MANNING JAMES, warehouse foreman for the Houston Oil Company, has been transferred from Pettus, Southwest Texas, to the Conroe field, where the company is developing some important properties.

L. E. ASHLY, formerly oil gauger at the Okmulgee, Okla., station of the Great Lakes Pipe Line Company, has been promoted to engineer and is now located at the company's Muskogee, Okla., station.

W. H. CONNOR and E. G. HARVEY, representatives of Black, Savalls & Bryson, Inc., with headquarters at Casper, Wyo., have completed a business tour through northern Wyoming and southern Montana.

A. J. WELBORN, previously warehouse foreman for the Simms Oil Company at Longview, Texas, has been transferred to the company's headquarters at Dallas, Texas.

W. C. TROUT, vice-president and general manager of Lufkin Foundry & Machine Company, Lufkin, Texas, has been calling on the oil trade in California fields.

E. R. SPENCER, mechanical engineer with the Texas Empire Pipe Line Company, has been transferred to Houston, Texas, from Tulsa, Okla.

J. J. MCNERNEY, formerly vice-president and general manager of the Hyvis Oil Refining Company of California, Los Angeles, has been elected president of the newly organized Hyvis Oils, Inc., Warren, Pa. This company has recently taken over the Conewango Refining Company, Warren, Pa., and the Fred G. Clark, Inc., Cleveland, Ohio. Harry R. Lewis, president of the Conewango, becomes vice-president of Hyvis Oils, Inc.

C. V. MILLIKAN, chief production engineer for the Amerada Petroleum Corporation, Tulsa, Okla., was a business visitor to Houston and other Texas oil centers during the past month.

G. S. ROLLIN, vice-president of the Shell Petroleum Corporation, is returning to his former place of residence, having recently been transferred from St. Louis, Mo., to Tulsa, Okla., where he once made his home.

F. E. COURSON, independent oil producer, previously of Wellsboro, Pa., is now a resident of Jackson, Miss.

CHARLES C. PRUITT, field foreman for the Sinclair-Prairie Oil Company, has been transferred from Borger, Tex., to Whittenburg, Texas.

E. A. Showers of Showers & Moncrief, independent oil producers, has changed his headquarters from the Stucky Building, Longview, Texas, to 809 Second National Bank Building, Houston, Texas.

T. L. Todd, field foreman for the Gulf Production Company and formerly located at Holliday, Texas, is now at Archer, Texas.

C. W. Alcorn, field petroleum engineer for the Shell Petroleum Corporation, has moved from Houston, Texas, to Tulsa, Okla.

E. N. Foster of the Gulf Production Company is now serving as chief clerk for the company at Wink, Texas. He was previously a member of the Fort Worth, Texas, personnel.

L. A. Ogden, formerly with The Empire Companies, Bartlesville, Okla., is now affiliated with The Pure Oil Company at Tulsa, Okla. He is serving as production engineer for the southwestern producing division.

Carl Short, 3503 Dickason Street, Dallas, Texas, and John R. Black, 1401 Tower Petroleum Building, Dallas, Texas, have formed the firm of Carl Short, Inc., drilling contractors.

R. K. Tracy of the petroleum engineering department, Humble Oil and Refining Company, Houston, Texas, has been transferred to Thompson Dome field, Gulf Coast, Texas.

A. V. Wadsworth, vice-president and general manager, Westcott Valve Company, East St. Louis, Ill., was a recent visitor in Tulsa and other Oklahoma points.

C. W. Breukelman, petroleum engineer formerly with the Bataafsche Petroleum Mij at Netherland Tjepoe, Java, Dutch East Indies, is now connected with the Sarawak Oil Fields, Ltd., at Miri, Sarawak.

Paul L. Brooks has been promoted to sales manager of the Parkersburg Rig & Reel Company and has moved from Dallas, Texas, to Parkersburg, W. Va.

Joe LaFortune, vice-president of the Western Gasoline Corporation, Tulsa, Okla., was a recent visitor to Dallas, Texas, and the East Texas oil field.

K. Chickering of the Oil Well Supply Company has been transferred from Oil City, Pa., to Dallas, Texas, where he will handle publicity, among other duties.

M. P. Hare, 2602 Catherine Street, Dallas, Texas, has been appointed district representative for Shand & Jurs Sales Company, Denver, Colo., a subsidiary of Shand & Jurs Company of Berkeley, Calif.

Wallace H. Collins, formerly petroleum engineer, has been made production superintendent of the Shell Petroleum Corporation, Tulsa, Okla., succeeding the late S. R. Gilland.

F. W. Stork, president of the Stork Engineering Company, Saginaw, Mich., was a recent visitor in the Mid-Continent and Gulf Coast fields.

C. D. Buffett has been made superintendent of the Rocky Mountain producing division of the Stanolind Oil and Gas Company. He has established headquarters at Casper, Wyo.

Sam Monroe, division machinist for the Stanolind Pipe Line Company, has moved from Tulsa to Wirt, Okla., and will devote his time to the company's stations in southern Oklahoma.

J. J. Zorichak, former district engineer of the Midwest Refining Company at Salt Creek, Wyo., is now an assistant to the chief engineer of the Stanolind Oil and Gas Company in Tulsa, Okla.

David G. Hawthorn, production engineer with the Barnsdall Oil Company, Tulsa, was married on February 14, to Miss Lois Burton of that city.

Walter Miers, chief engineer of the Atlantic Oil Producing Company, Dallas, Texas, has been confined to his bed with illness for some time.

H. K. Browning, director of oil country sales of the A. M. Byers Company, Pittsburgh, Pa., has completed a tour of the Mid-Continent and Gulf Coast oil fields. Mr. Browning, accompanied by H. B. Weathersby, division manager for the company at Houston, Texas, spent some time in Dallas while on this trip.

B. J. Smith of Wichita Falls, Texas, and Bowman Thomas of Goose Creek, Texas, have been transferred to the Humble Oil and Refining Company's Houston, Texas, office, where they will be in the petroleum engineering department.

Byron E. Hepler, formerly vice-president and treasurer, was elected president of the Hope Engineering Company, Mt. Vernon, Ohio, at a meeting of the board of directors. He succeeds Raymond S. Lord, who died recently. Mr. Hepler is also president and a director of Rio Grande Valley Company and General Funding Corporation. He is vice-president and a director of the Northwest Stellarene Co., Inc., and a director of Kelly-Springfield Tire Company.

Rudolph Furrer, formerly chief engineer and director of research of A. O. Smith Corporation, and also engineer for the Allis-Chalmers Manufacturing Company, comes to the National Tube Company, Pittsburgh, Pa., as assistant to the operating vice-presidents, to further extend their research and engineering studies.

Pete Parker, field superintendent for the Doheny Stone Drill Company, Los Angeles, Calif., is on an extended visit to active Mid-Continent oil fields.

F. C. Eibell, who for the past four years has been manager of the advertising and publicity department of the Worthington Pump and Machinery Corporation, New York, N. Y., has resigned.

Carl W. Vogt has recently been made factory representative in the Mid-Continent and Gulf Coast for the Shaffer Tool Works of Brea, Calif.

Casing Cementing Device Prevents Channelling

Spiral V-shaped rubber strip on outside of casing is simple and effective aid insuring secure cementing job in tight hole

FREQUENTLY the success and permanency of a casing cementing job are in doubt because of the possibility that the cement has channelled on the outside of the casing. As is well known, channelling can be the starting point for trouble of the insidious kind that defies detection until serious damage is done; for example, water gradually seeping into the well from overlying water strata. Well conditions that give rise to channelling are many, but the usual evidence, and that most easily observed while running casing, is a tight place in the hole. Too often, however, there is no evidence of any kind that is easily discernible by which the possibility of channelling can be detected from the surface. Cavey formation, crooked hole, extremely hard formation, hard shells and hole out of round are some of the aggravating conditions that lead to channelling.

It cannot be denied that, under present-day drilling practices, great strides have been made in eliminating many of the uncertainties that enter into the proper completion of a well; nevertheless, despite all the precautions that are taken while drilling to obviate the possibility of channelling when the casing is cemented, channelling does occur. Any extra assurance, therefore, that can be given to the operator that the casing is securely cemented, is highly desirable.

A simple and effective device designed to prevent channelling when casing is cemented has recently been put into successful use in the field. It is known as the Howco Co-axial Cement Spiral, and consists of a rubber strip of triangular cross-section backed by a metal strip, by means of which it is tack-welded to the outside of the casing. Instead of the rubber strip being wound around the outside of the casing in a continuous spiral as shown in the illustration, the spiral is staggered at 7-ft. intervals between couplings on the joint of casing, the purpose being to deflect the passage of the cement at intervals on its way up the annular space around the outside of the casing and thus prevent channelling.

Sketch showing how the spiral strip holds the casing off the wall of the hole, thus insuring an annular space around the entire outside for placing the cement.

The cross-sectional dimension of the rubber strip varies with the size of the casing. It is made to suit all sizes of A.P.I. casing in use in the field. The outside apex of the rubber strip projects beyond the outside diameter of the casing coupling, the amount depending on the size of the casing. It is to be noted, however, that the part of the rubber strip that does project beyond the outside diameter of the casing coupling is quite flexible, as it allows the casing to pass with ease through tight places in the hole that the coupling may find difficulty in getting through.

Referring to the illustration it will be seen that the spiral rubber strip acts as a guide when running the casing in the hole, besides fulfilling its chief purpose of keeping the casing and coupling from touching the wall of the hole, by which means it insures an annular space around the entire outside surface of the casing for the placing of the cement even though in a tight part of the hole.

Several strings of casing have been cemented with this device in the Conroe field. It was used there on 10¾-in., 12½-in., 13⅜-in. and 15½-in. casing, and was found to facilitate the running of the casing. The spiral can be placed at any desired point, but it is generally used on the casing shoe joint. Two sections may be used just above the shoe joint and at any desired intervals above. The device is a simple, effective and efficient means of insuring a secure casing cementing job, and removes much of the uncertainty that often attends this phase of well completion.

LAUGH WITH BARNEY

Edited by BARNEY HORRIGAN

Oklahoma City Oil Man to Barber: Give me a Cicero shampoo.
Barber: A Cicero shampoo?
Oil Man: Yes, hot oil.

* * *

Maybe So

Betty: If that boy never necks you, why do you go around with him?
Jane: Oh, he's such a relief after a hard day at the office.

* * *

Toolie: Give me a date sometime, will you?
Waitress: Sorry, but I can't go out with a baby.
Toolie: Pardon me. I didn't know about it.

* * *

Others Would Like to Know

He: It is all so simple, my dear. We can go away together on a trial honeymoon and after a time, if we find we have made a little mistake we can separate.
She: Yes, but what'll we do with the little mistake?

* * *

Jailer (to prisoner awaiting execution): You have an hour of grace.
Prisoner: Thanks. Bring her in.

* * *

Judge (to prisoner): What, you here again?
Prisoner: Yes, sir.
Judge: Aren't you ashamed to be seen here?
Prisoner: No, sir. What's good enough for you is good enough for me.

* * *

He: I loved you more than you know.
She: How dared you take advantage of me while I was drunk!

* * *

Old Lady: I suppose that this is another of those terrible futuristic paintings?
Clerk: I'm sorry, madam, but this is a mirror.

* * *

Bystander: I observe that you treat that gentleman very respectfully.
Storekeeper: Yes, he's one of our early settlers.
Bystander: Early settler? Why, he's not more than 30 years of age.
Storekeeper: That may be true, but he pays his bills on the first of every month.

* * *

C. A. E. Gower, with White Eagle Oil and Refining Company, Kansas City, Mo., has submitted this one:

"An engineer is said to be a man who knows a great deal about a very little, and who goes along knowing more and more about less and less until finally he knows practically everything about nothing; whereas a salesman, on the other hand, is a man who knows a very little about a great deal, and keeps knowing less and less about more and more until finally he knows practically nothing about everything."—From *Automotive Industries.*

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Explosion-proof motors are described in Part 5 of Bulletin 174. Ask for a copy.

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Greek captains turned back a Carthaginian elephant corps in the first Punic War (264-241 B. C.) by sending burning swine among them. The swine had been covered with petroleum and set afire.
Twenty years ago kerosene was the principal product manufactured from crude oil and gasoline, a certain amount of which had to be made when making kerosene, was purposely pumped to a sump and burned as waste.
A well at Love Lake, Texas, had a flow so strong that a sledge could not be driven through it.

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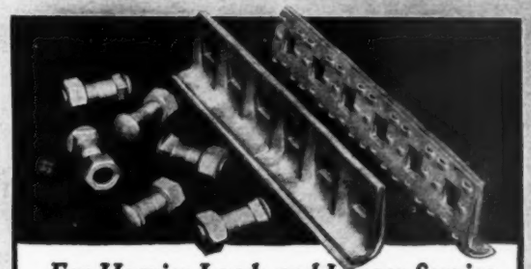

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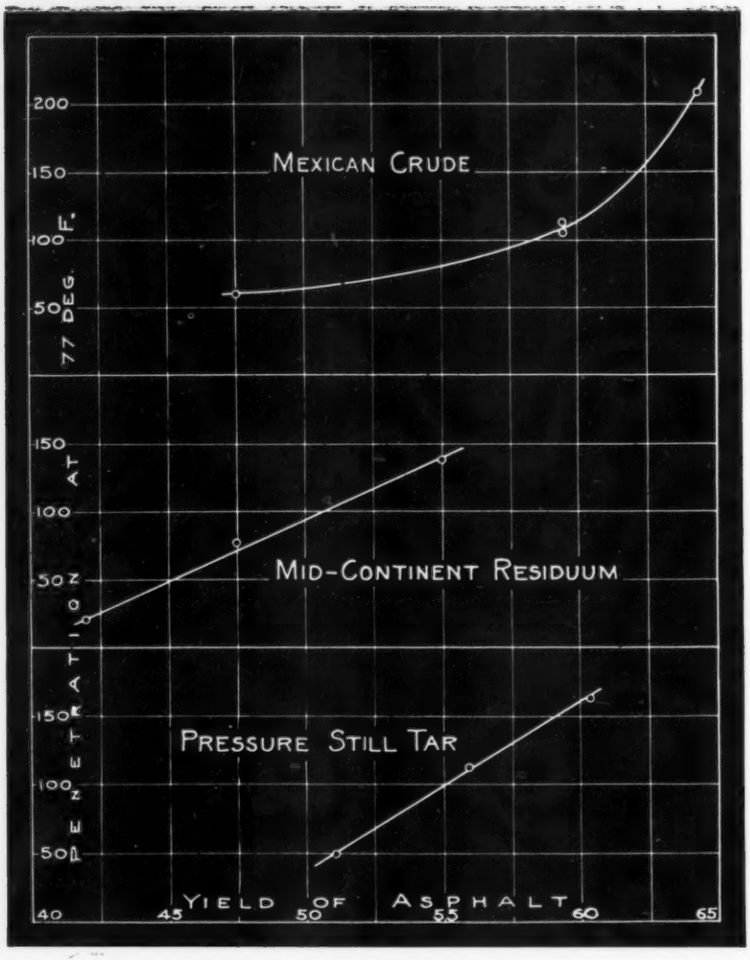

Fig. 1—Yield of asphalt

Evaluation of A

By
W. L. NELSON
Professor of Petroleum Refining
University of Tulsa

THE last three years has brought a great increase in the use and manufacture of petroleum asphalt and road oil. For many years petroleum asphalt materials have constituted the major bulk of all asphaltic products, but until recently these products have been manufactured by a few companies and from crude oil stocks that have long been recognized as particularly suitable for asphalt manufacture. Now we have found that almost all oils are suitable for asphalt manufacture although most of them contain such small quantities that processing for asphalt is not feasible. Even cracked fuel oils have been found to be satisfactory and some, particularly those from processes in which little coke is formed, have been found to yield asphalts having combinations of properties that are superior to the properties of straight residues.

The reason for the increased interest in road oils is the general recognition of the fact that concrete and the more expensive roadways are foolishly unnecessary for most of our highway traffic. Oiled roadways or asphalt concrete will probably never be as durable or as generally satisfactory as concrete, but for the expense involved and for certain types of service such as the rural roadway, an asphalt-concrete or even an oiled roadway is exactly what is needed. These types of roadways have been in service for many years, but they have not always been considered as successful. However, these failures usually should not be charged against the type of roadway itself. In many cases the service has been too severe and asphalt should never have been used. In other words, asphalt concrete will not stand up under severe traffic and should never be expected to do so. In other cases the roadways were not properly constructed and of still more importance, they were not regularly and carefully repaired. Today information is available to all who desire it concerning the proper construction and upkeep of asphalt concrete highways, so that there is no reason for a repetition of the failures of the past.

Another fact that should not be overlooked is the fine road-base for concrete construction that results by the proper upkeep of an oiled roadway. Thus a community may start preparation for a concrete highway by temporarily using an asphalt-concrete or oiled roadway.

Uses of Petroleum Asphalts

By far the greatest quantity of asphaltic material that is manufactured today is road oil. The term road oil has been used in the past to designate a fluid residual oil for the purpose of "laying" the dust on dirt or gravel roads. Gradually the term, or perhaps it would be better to say speci-

TABLE I

	Usual Range	Limiting property which may be difficult to obtain
Sp. Gravity at 77° F.	0.95 — 1.03	0.95+
Asphalt Content (100 Pen. at 77° F.)	40 — 85%	85+
Asphalt Content (80 Pen. at 77° F.)	35 — 94%	94+
Furol Viscosity at 210° F.	Wide Range	.....
Solubility in CS_2	99 — 99.5	99.5+
Percentage Asphaltenes	4 — 15	either extreme
Flash Point (o.c.)	120 — 400	400+
Evaporation Loss		
Residue Oils	1 — 15%	1—
Cut-Back Oils	2 — 40%	2—
Ductility of Asphalt Content	1 — 100	100+

TABLE II

	Penetration at 70 deg. F.	Ductility at 77 deg. F.	Melting Point R & B
Paving Binders			
Mastic Foot Pavements and Floors	10–15	.....	180–220
Asphalt Blocks	10–25	20+	.....
Sheet Asphalt Pavement	25–40	40+	105–140
Grout Filler	40–70	50+	113–140
Grout Filler (blown type)	30–50	3+	150–230
Asphalt Concrete (aggregate, sand, etc.)	30–70	45+	113–150
Asphalt Macadam	70–150	90+	104–113
Roofing Asphalts			
Saturant for felt or paper	75–140	100+	110–120
Heavy saturant for felt and rugs	28–32	40+	140–150
Roof coatings (blown)	10–50	1+	160–260
Sealing			
Pipe sealing (sewers, etc.)	40–60	1+	200–225
Pipe coatings	10–15*	1+	200–215
Waterproofing	25–50	15+	140–170

*Consistency.

Asphalt-Bearing Stocks » » » »

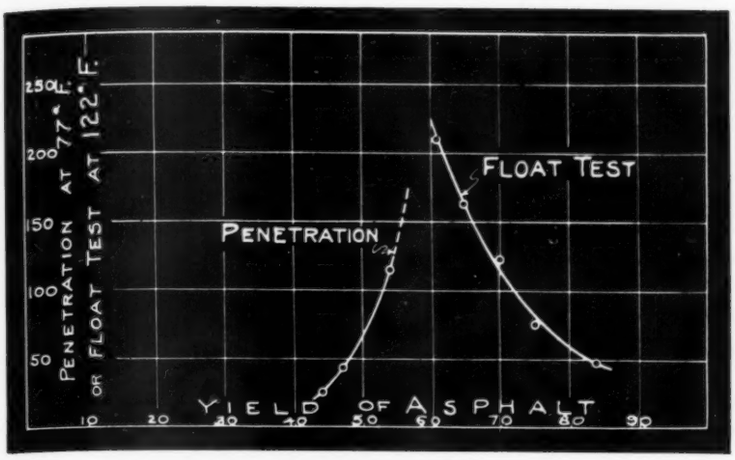

Fig. 2—Yield data on cracked tar

Almost all oils are suitable for asphalt manufacture, but many contain quantities too small for practical processing

fication, for road oil has changed until today a road oil is produced that is more viscous than that produced heretofore; one that contains a high percentage of solid asphalt. Upon exposure, the more volatile portion of the oil evaporates or is absorbed by the earth or the aggregate, leaving an asphalt binding material.

The purpose in presenting the following tabulation of road-oil properties is not as a specification but rather as an indication of the most severe requirements that any state specification may contain. Usually a refiner is more interested in the general usefulness of his stock for asphalt manufacture than in the suitability of his stock for the manufacture of a particular asphalt or road oil. Thus, a stock from which road oils can be made whose properties meet all the following property ranges, can be considered as suitable for the manufacture of *any* kind of road oil. (See Table I).

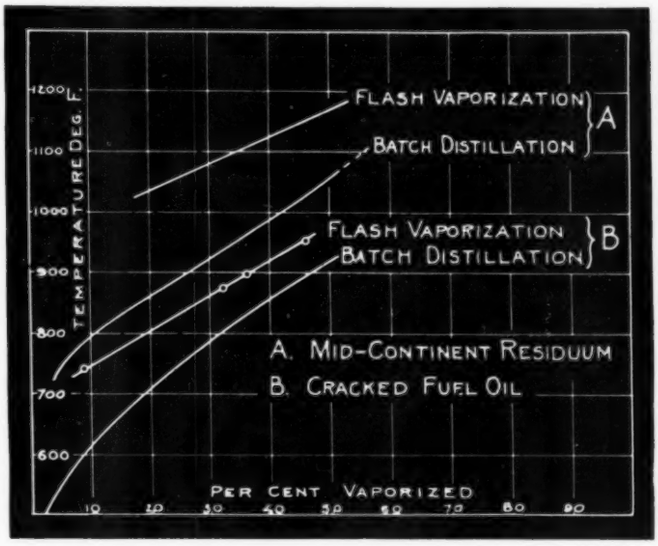

Fig. 3—Flash vaporization data

A tabulation of many of the state specifications was printed in this magazine by F. R. Staley, June, 1932, (page 35).

Table II indicates the entire range of petroleum asphalt materials. These again are more for convenience in the evaluation of a stock for asphalt manufacture than as a set of specifications.

Of course there are many other properties that are specified, but if the above combinations of properties can be obtained, usually little difficulty arises in meeting the other requirements.

Testing Methods

Exact test methods for examining asphalts are available in many sources. The purpose in the following discussion is to indicate the general relation between tests rather than to explain test procedures. The common tests may be grouped as follows: 1. Consistency or fluidity tests; 2. Ductility tests; 3. Boiling range or evaporation tests; 4. Solubility tests; and 5. Impurity tests.

Consistency Tests. This group indicates the relative ease with which the material flows. By means of viscosity, float test, consistency, penetration and hardness, the entire range from fluid to solid is covered. For liquid materials the Engler or Furol viscosity is used. For semi-solids the Float Test is used. This test is a measure of the time required for a plug of the material to be pushed through the bottom of an aluminum float as the float rests in hot water. The various consistency testers are used for about the same class of semi-solids and one of these, the consistometer, is also used for the very hardest solids. Consistometer readings are governed by the weight required to cause a plunger to penetrate the solid at a specified rate. The penetration test is used for the solid asphalts. The test is a measure of the depth that a standard needle penetrates under a specified load during a specified length of time.

Ductility Tests. The extent to which the material can elongate without rupture is called the simple ductility test. In this test a briquet of the material is pulled apart under water. The tensile strength tests are to be compared with ductility tests except

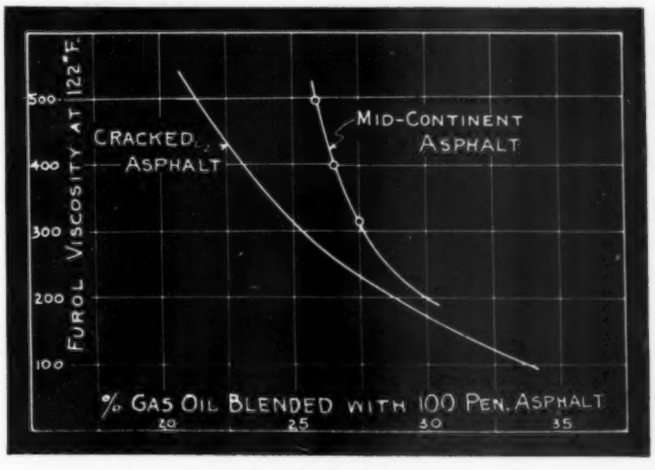

Fig. 4—Cut-back blends

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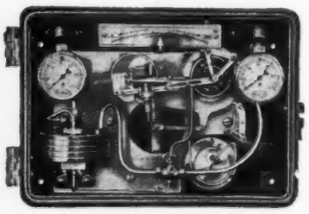
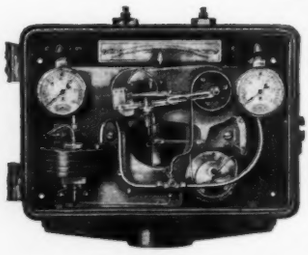
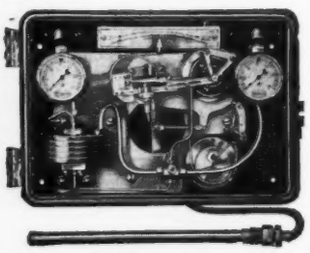


PRESSURE



FLOW



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that the cohesiveness rather than the elongation is recorded.

Boiling Range. Since asphalts cannot be distilled at atmospheric pressure without decomposition, distillation tests have never been widely adopted. The boiling range is usually measured by evaporation tests. In one of these the sample is heated at 325 deg. fahr. for five hours and the percentage loss is reported. In the other common test 100 grams of the material is heated at 490 deg. fahr. for a time sufficiently long to leave a residue of specified penetration (usually 100 at 77 deg. fahr.). The percentage residue is termed the asphalt content. Evaporation for asphalt content is not used extensively except for road oils. In the case of cut-back oils the diluent oil evaporates fairly quickly at 490 deg. fahr., leaving a residue of about the same percentage of asphalt as was used in the blend. For straight residue road oils the asphalt content may increase sharply during the long (five plus hours) evaporation at 490 deg. fahr. At the same time the ductility of the asphalt residue may decrease.

Solubility Tests. The solubility tests are used mainly for purposes of identification, control of manufacture and gauging the uniformity of supply. Overblowing or overheating in the presence of even small amounts of air results in a smaller solubility in CS_2 and large amounts of carbenes. A comparison of solubilities follows:

	Relatively *High*	*Low*
Insoluble in CS_2 (inert matter) -	Coal Tar	Petroleum
Insoluble in CCl_4 but soluble in CS_2 (carbenes) - - - - -	Natural Bitumins	Petroleum
Insoluble in Pet. Naphtha (asphaltenes) - - - - - -	Coal Tar	Petroleum

Impurity Tests. These tests are all quite similar to the common quantitative analysis practice and since they are dependent more on the inherent properties of the raw stock rather than upon processing, they need not be discussed.

As evidenced above, most asphalt tests are empirical in nature and therefore it is difficult to find a relation between behavior in practice and the test results. For this reason many criticisms and discussions of test methods have appeared during the last few years, with the result that weathering tests, etc., that simulate conditions during use are rapidly gaining in favor.

Evaluation Procedure. It will be found that far-sighted refiners are not entirely interested in evaluating their raw asphalt stock for a particular market specification, rather they are interested in determining the general usefulness or value of their stock for the manufacture of a wide range of asphalt products; hence, the following evaluation procedure is for the purpose of determining the all-'round value of a raw asphalt stock.

In the design of distillation equipment the following data are necessary: 1. Yields; 2. Distillation curve; and 3. Flash vaporization data if pipe-still processing is proposed.

Yields are best approached by running a series of batch vacuum distillations covering a range of about 25 to 200 penetration at 77 deg. fahr. or if semi-solid asphalts for plant manufactured paving concretes are considered as a market, the float test from 20 to 100 at 122 deg. fahr. should also be determined. Ductility tests should be determined on the penetration asphalts starting with the low penetration asphalts and testing softer ones until asphalts of ductility of 100 plus are reached. Likewise, each of the float test samples should be evaporated at 490 deg. fahr. to determine the yield and

ductility of 100 penetration asphalt-content. The viscosity temperature relation will also be found useful so that a series of penetrations at three temperatures, float tests at three temperatures, or viscosities at three temperatures should be determined, depending of course upon the type of material whether it be solid, semi-fluid or fluid. Frequently the asphalt content is greatly increased (also loss of ductility) in the evaporation test at 490 deg. fahr. In two pronounced cases in my experience the asphalt content increased from 66 to 90 per cent and from 45 to 82 per cent, respectively.

Figure 1 illustrates penetration data on three asphalt stocks, and Figure 2 float test data.

The distillation curve is most useful from a design standpoint if it is obtained in fractionating equipment, but since asphalt stocks distill at such high temperatures (700 to 1500 deg. fahr. converted to 760 mm) a fractionating type of distillation is usually impossible. The most satisfactory distillation is the vacuum 10 per cent distillation conducted in a manner similar to the A.S.T.M. procedure but using a 250-cc. flask for a 100-cc. sample. Foaming can be avoided by heating the sides and neck of the flask but the thermometer must be shielded from radiation by asbestos sheet. Temperatures that are high by 50 deg. fahr. have come to my attention in distillations in which the shield was omitted.

Most modern asphalt plants are of the vacuum tower and pipe-still type. In operating such a plant the vaporizer temperature is the most important single design factor. This temperature must be determined experimentally by obtaining equilibrium flash vaporization data under vacuum. Yield data are obtained at the same time but these yield data cannot be relied upon because a poor separation is obtained in this type of distillation. The residue by flash vaporization has a lower flash point, lower viscosity and lower asphalt content than the same percentage of residue obtained in a batch distillation. Even the product from the plant, even though flash vaporization is practiced, does not correspond to laboratory flash vaporization yield data because in the plant the poorly separated flash residue is stripped and even fractionated to some extent in the vacuum tower.

Flash vaporization data for these heavy stocks cannot be accurately estimated by the common correlation methods. Figure 3 shows the wide variation that may be expected for stocks which in other ways may appear to be alike.

Cut-Back Road Oils. In manufacturing cut-back road oils the refiner usually keeps stocks of solid asphalts on hand with which he blends gas oils, etc., in order to meet several different state markets. Figure 4 illustrates two sets of blend data in which Furol viscosity is plotted against percentage of asphalt. If straight residues and cut-back oils are used, the asphalt content by evaporation at 490 deg. fahr. will generally be the same as the percentage of asphalt originally blended. However, if cracked asphalts or cracked cut-back oils are used the asphalt content may increase sharply. This may also be true if very high boiling cut-back oils are used.

Property Tests. The above yield evaluation was based upon penetration and ductility alone. If these two tests and the viscosity change with temperature are satisfactory the other common specifications such as specific gravity, melting point, solubility, fixed carbon, water and sediment, sulphur, etc., will usually be satisfactory if the materials were manufactured from straight petroleum residues. Blown asphalts would need to be examined more completely. Usual practice is to determine these extra tests on one or two asphalts and if these meet the most rigorous specifications, then the properties of the other asphalts may be expected to be satisfactory.

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Control of Combustion of Mixed Fuels by Flue Gas Analysis

By MYRON J. BURKHARD
Refinery Engineer

CONTROL of combustion of a single fuel by Orsat analysis, the composition of the fuel being known or capable of reasonably accurate estimation, is comparatively simple, as the interpretation of the Orsat analysis of flue gas, when compared with the fuel analysis, leads readily to a figure for the percentage of excess air present in the flue gas.

Modern refinery practices have led to a more complex situation. Mixtures of fuels are fired, and any one combustion may be fed by a ever-varying mixture, in which still gases, fuel oil, pulverized coke, waste sludges and slops, and even pulverized coal, are frequently present. Analysis of the fuels and charts based on any momentary combination of fuels are of little value as the proportionate amounts usually vary continuously, one or more fuels carrying the base load and seldom being adjusted, and some other fuel being varied in amount to care for variations in load. Even on constantly loaded combustions, the fuels usually vary in amount and quality among themselves, thus upsetting any chart based directly or indirectly on fuel analysis, as for instance, charts based on a supposed maximum CO_2.

It is not believed to be known generally that a simple equation based on the Orsat analysis can be used as the basis of a chart that can be used for any analysis of fuel. The equation (originally presented by the Bureau of Mines), is, in a modified form:

$$\frac{N_2 \times 100}{N_2 - 3.78\ O_2 + 1.89\ CO} - 100 = \text{per cent excess air.}$$

Only one assumption is necessary in the use of this formula. That is that the fuel as fired shall not contain CO_2, CO, or free O_2 and N_2. The most commonly used fuels not meeting this requirement are blast furnace and producer gases, and neither of these is likely to be met in a refinery. Fuel gases from a vapor recovery plant, particularly when storage tank vapors are treated, are likely to contain air. The presence of air in these vapors impairs the efficiency of vapor recovery, their amount is minimized as far as possible, and information as to the amount present in fuel gases is usually available to the combustion department from those in charge of gas recovery. When this is known, proper correction can be made. With the exception of this one fuel when in an exceptional condition, refinery fuels all lend themselves to this method of control.

The Orsat analysis of flue gas shows the amounts of CO_2, Co, O_2 and N_2 by difference in volume percentages. To make use of these in developing the Bureau of Mines formula, we require the following data:

N_2 = volume percentage nitrogen
O_2 = volume percentage oxygen
CO = volume percentage carbon monoxide
CO_2 = volume percentage carbon dioxide
Air contains 79.09 per cent N_2 by volume.
Air contains 23.15 per cent O_2 by weight.
1 lb. CO requires 0.571 lb. O_2 to burn to CO_2.
1 cu. ft. air at standard conditions weighs 0.0807 lb.
1 cu. ft. oxygen at standard conditions weighs 0.0892 lb.
1 cu. ft. CO at standard conditions weighs 0.0780 lb.

The formula may be developed as follows:

1. Lb. air represented by one cu. ft. flue gas
$$\frac{N_2}{0.7909} \times 0.0807 = \frac{N_2}{9.8}$$
2. Lb. O_2 supplied to combustion per cu. ft. flue gas
$$\frac{N_2}{9.8} \times 0.2315 = \frac{N_2}{42.4}$$
3. Lb. free O_2 in one cu. ft. flue gas
$$O_2 \times 0.0892 = 0.0892\ O_2$$
4. Lb. O_2 consumed by combustion per cu. ft. flue gas
$$\frac{N_2}{42.4} - 0.0892\ O_2$$
5. Lb. CO per cu. ft. flue gas
$$= 0.0780\ CO_2$$

A chart based on this solution is given, from which, knowing the Orsat analysis of flue gas, the percentage of excess air may be easily determined.

To trace the example given, we enter the chart at the vertical N_2 axis at 80.7, proceed left horizontally to $O_2 = 6.3$ per cent, then vertically to CO = 0.0 per cent, then horizontally to $N_2 = 80.7$ per cent on the

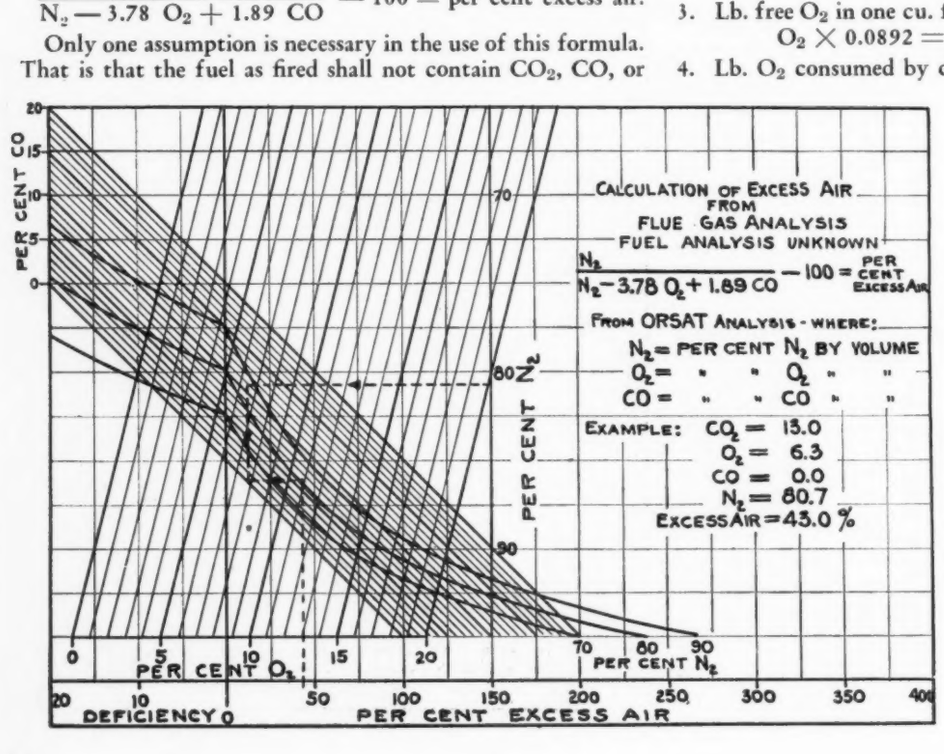
PER CENT CO
CALCULATION OF EXCESS AIR FROM FLUE GAS ANALYSIS FUEL ANALYSIS UNKNOWN
N2 / (N2 − 3.78 O2 + 1.89 CO) − 100 = PER CENT EXCESS AIR
FROM ORSAT ANALYSIS - WHERE:
N2 = PER CENT N2 BY VOLUME
O2 = " " O2 " "
CO = " " CO " "
EXAMPLE: CO2 = 13.0
O2 = 6.3
CO = 0.0
N2 = 80.7
EXCESS AIR = 43.0 %
PER CENT N2
PER CENT O2
DEFICIENCY 0
PER CENT EXCESS AIR

Chart for determining the percentage of excess air from an Orsat analysis of the flue gas

curved N_2 scale, then vertically to 43 per cent excess air.

6. Lb. O_2 to burn monoxide in one cu. ft. flue gas to dioxide

$$0.0780\ CO \times 0.571 = 0.0446\ CO$$

7. Lb. O_2 to perform complete combustion of fuel represented by one cu. ft. flue gas

Item 4 + Item 6

$$\frac{N_2}{42.4} - 0.0892\ O_2 + 0.0446\ CO$$

8. Lb. air to perform complete combustion

$$\text{Item } 7 \times \frac{1}{0.2315}$$

$$= \frac{N_2}{9.8} - 0.385\ O_2 + 0.1925\ CO$$

9. Ratio of air actually fed to air required

Item 1 ÷ Item 8

$$= \frac{N_2}{N_2 - 3.78\ O_2 + 1.89\ CO}$$

10. Excess air

$$\frac{N_2 \times 100}{N_2 - 3.78\ O_2 + 1.89\ CO} - 100 = \text{per cent excess air.}$$

J. T. Dillon, Jr., New Struthers-Wells Head

J. T. Dillon, Jr., was made president of the Struthers-Wells Titusville Corporation, Warren, Pa., at a recent meeting of the Board of Directors. Mr. Dillon for several years has been president of the Titusville Forge Company and vice-president of the Titusville Iron Works Company, affiliated organizations, and is well known throughout the oil industry. In addition to his executive duties, Mr. Dillon has been active in many of the engineering developments fostered by the Titusville interests.

Oil Equipment Exposition to Be Held in Houston

According to an announcement by E. G. Lenzner, a change has been made in the location and date of the Oil Equipment and Engineering Exposition. Originally scheduled to be held in April at Dallas, the show will now be held at Houston, Texas, May 22 to 28, 1933.

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Alcohol-Ga
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WHATEVER the merits of an alcohol-gasoline blend of motor fuel elsewhere, it is clear that the advocacy of its use in the United States is all too premature. Indeed, to consider it from the farmer's standpoint and advocate it as an outlet for surplus grain, there is less basis upon which its use as a motor fuel can be justified than upon any other score. There are technical and economic difficulties and complications galore that must be overcome.

Ethyl alcohol as manufactured by ordinary commercial methods is only 95 per cent pure, the remaining 5 per cent being water. It is physically and chemically impossible with ethyl alcohol of this degree of purity to obtain a stable blend of gasoline because the very presence of water, even in small percentages, will cause the gasoline and alcohol to separate. Gasoline and ethyl alcohol of almost 100 per cent purity will mix in all proportions, but alcohol of this degree of purity, even when blended with gasoline, has a great affinity for water, resulting in a mixture that is unstable unless care is taken to keep it in airtight containers; and to raise ethyl alcohol of 95 per cent purity to a sufficiently high degree of purity would increase its cost of manufacture about 25 per cent.

If ethyl alcohol of 95 per cent purity is to be used, a blending agent is required. Benzol and the higher alcohols make suitable blending agents. For a 10 per cent alcohol blend, using alcohol of 95 per cent purity, 20 per cent benzol is required for a stable blend. If the higher alcohols, of which crude ethyl alcohol contains about 2 per cent, only 5 per cent is required as a blending agent.

To manufacture a gallon of ethyl alcohol from the cheapest raw material, which is cheap molasses, and under the most favorable conditions, the cost is 20 cents per gallon. To manufacture it from grain, the cost is even higher. With corn at 25 cents a bushel, the cost of manufacture would be about 25 cents; at 50 cents a bushel, 30 cents; and at 75 cents a bushel, 36 cents a gallon. Add to this the cost of a blending agent (as benzol at 15½ cents per gallon or a higher alcohol at 75 cents per gallon) an alcohol-gasoline blend of fuel will cost from 10 to 12 cents per gallon greater than the cost of gasoline at the refinery. So far as the farmer is concerned, he would need to be paid about 75 cents a bushel for his grain at the alcohol plant in order to offset the increased cost of using an alcohol-gasoline motor fuel.

Compared to 120,000 B.t.u. per gallon for gasoline, ethyl alcohol contains only 85,000 B.t.u. per gallon, and the mileage obtainable from an alcohol-gasoline fuel will be 4 per cent less for each 10 per cent of alcohol added. This fact, together with the increased cost of the fuel, would more than offset any advantage that might be gained by the increased antiknock rating of an alcohol-gasoline blend of fuel.

To use an alcohol-gasoline blend of fuel in an automobile engine it is necessary to make changes in the carburetor if normal efficiency is to be obtained. Jets must be enlarged and these will not work satisfactorily on gasoline, hence a subsequent change of fuel could not be made. The shellac in cork floats used in carburetors and gasoline tanks is soluble in alcohol; this would result in clogging the fuel line to the engine. Moreover, there is a considerable tendency toward corrosion because of the acids that are present in alcohol admixtures. Trouble from this source would prove quite serious with the

Gasoline Serious Drawbacks

passing of time. Of all the obstacles to the use of alcohol-gasoline fuels that arise the most serious is the tendency to separate at moderately low temperatures into two layers of widely different characteristics in the presence of a very small amount of water. In the presence of even 2 per cent of water, alcohol-gasoline blends that are stable when warm will separate when cold.

Taking into account the increased distribution costs and the cost of handling and blending, the political difficulties are tremendous. As alcohol is more costly than gasoline, it is obvious that manufacturers would not use it unless the law was made absolutely compulsory. A small army of government agents would have to be employed to watch refineries and distilleries, to inspect gasoline at wholesale and retail outlets, and to check up on imports into the State affected. New complications would be added to the problem of gasoline taxation, which already is a source of grave economic difficulties in the oil industry.

In foreign countries where alcohol is used as a blended motor fuel, it is manufactured locally, usually by a government subsidized monoply, but the gasoline is an imported product subject to high import duties and taxes. In countries having no petroleum supplies of its own, the cost of gasoline varies with the distance from the point of production and the amount of duties and taxes that must be paid on it, whereas alcohol is approximately constant in cost anywhere in the world. Moreover, the fact that the alcohol is a home product, while the gasoline is imported, has aided in fostering the use of alcohol-gasoline blends in foreign countries.

It is a significant fact, however, that, despite such conditions and the high prices that obtain for gasoline in these foreign countries, the use of alcohol-gasoline motor fuels are not popular. In France, for example, where gasoline importers are compelled to buy alcohol in amounts equal to 10 per cent of the gasoline imported, the use of alcohol blends of fuel is confined almost to government operated vehicles; the alcohol-gasoline fuels are regarded with disfavor. In Germany, where somewhat similar conditions obtain, except that importers are not compelled to blend the alcohol they must purchase with imported gasoline, the alcohol is sold back to the government at 80 per cent of the price paid for it. In other words, this compulsory purchase of a certain amount of alcohol with imported gasoline virtually amounts to an extra tax on imported gasoline. Despite these restrictions on gasoline, however, alcohol-gasoline motor fuel is not popular in Germany. Indeed, gas-oil as an engine fuel, and the use of Diesel engines are becoming popular in that country as a result of the obligatory use of alcohol-gasoline motor fuels. In Mozambique and Angola, Portuguese colonial possessions, the use of an alcohol-gasoline fuel, of 75 per cent gasoline and 25 per cent denatured alcohol, will become compulsory in July of this year. It is really an experiment, the success of which will depend upon whether or not it will be extended to continental Portugal.

In all these and other foreign countries the cost of gasoline is, at the very least, twice as great as it is in the United States; nevertheless, the use of alcohol-gasoline as a motor fuel as an economic measure has been a dismal failure. What hope, therefore, can it have as an economy measure in this country where gasoline sells at a price much lower than in any other part of the world?

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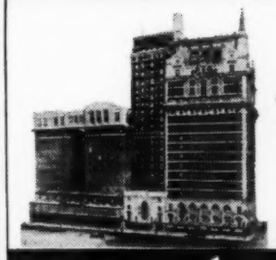

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